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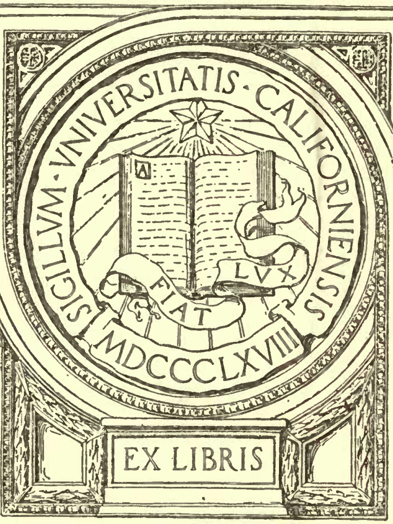

UNIV. OF CALIFORNIA

GEOLOGY IN THE FIELD.

THE JUBILEE VOLUME OF THE GEOLOGISTS' ASSOCIATION
(1858-1908).

Edited by H. W. MONCKTON and R. S. HERRIES.

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[WITH EIGHT PLATES.]

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visited by the Association under Professor W. J. Sollas, on May 9th, 1908.)

3 *Plateau Gravels* are found in several localities at elevations of more than 100 ft. above the present rivers. They are unstratified deposits not restricted to terraces, and consisting of pebbles derived from regions beyond the present drainage areas of the rivers.

These gravels have long been known under the name of the northern drift, and their glacial origin is supported by comparison with that of surrounding districts. Drift of this nature covers an extensive area to the west of Church Hanborough, and it is well seen lying on the Oxford Clay at "the Demesnes," near North Leigh.

The pebbles here consist of partially-rounded flints, liver-coloured quartzites, hard sandstones resembling greywethers, sandstones with felspar of the Millstone Grit type, lydian stone, etc. Many of these are subangular, but glacial striæ are extremely rare.

A description of this district would not be complete without some reference to the Oxford University Museum, "the oldest public collection ever formed in the British Isles for the illustration of natural history, etc.," which has frequently been visited during excursions of the Association. The Museum is exceptionally rich in vertebrate remains from the minute Stonesfield mammalia to the giant Cetiosaurus. The naming and arrangement of the stratigraphical collection, commenced many years ago, has now been completed by Mr. C. Hawker Dinham under the direction of Professor W. J. Sollas.

CHAPTER VIII.

BERKSHIRE AND PART OF THE THAMES VALLEY.

By H. J. OSBORNE WHITE, F.G.S.

THE following article contains a short general account of the geology of Berkshire and parts of the adjoining counties, illustrated by local stratigraphical details which are drawn, as far as possible, from Excursion Reports of the Geologists' Association.*

On the south, west, and north-west, the limits of the country with which the writer has been asked to deal are, practically, those of the county of Berks; but on the north-east, the Chiltern Hills of Oxfordshire and of a small portion of Buckinghamshire are included; while the villages of Coleshill and Taplow in the last-named county, and the towns of Maidenhead and Wokingham, in Berks, mark the position of the boundary on the east. As the south-eastern part of Berkshire, including Bracknell and Sandhurst, belongs mostly to the "Bagshot District," its description is left to Mr. H. W. Monckton, who has, geologically speaking, made that district his own.

The area above defined lies within the basin of the Thames, and includes, besides a lengthy section of that river, a great part of the Kennet and of the Ock, and the lower reaches of the Loddon. The Chalk upland of the Berkshire Downs and the Chilterns extends across it with an eastward to north-eastward trend, and separates the Oxford lowland from the Vale of the Kennet and the low ground between Reading and Windsor. The Secondary and Tertiary Strata here exposed have an aggregate thickness of about 2,000 ft., and, as their prevailing dip to the south-east makes a larger angle with the horizon than does the average slope of the ground in the same direction, they appear at the surface in descending order towards the north-west. Thus, the traveller crossing this part of the country, with his face set in the latter direction, leaves behind him the woods and sandy commons on the Eocene formations, and, mounting the long incline to the crest of the Chalk downs, sees, between the declivity at his feet and the rising ground of the distant Cotteswolds, an undulating plain on the Gault, Kimeridge, and Oxford Clays, broken by hills of Corallian limestone and Aptian sand.

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* Except where there are indications to the contrary, the references given in the footnotes to this article relate to Excursion Reports published in the PROCEEDINGS of the Geologists' Association.

JURASSIC.

The Oxfordian Series, which is the oldest formation exposed in Berkshire, comprises the following stages and zones:

" [STAGES.]	ZONES.	LEADING LITHOLOGICAL CHARACTERS.
OXFORD CLAY.	*Ammonites cordatus* [*Cardioceras cordatum*]	Clays with occasional septaria and ironstone-nodules.
		Clay, and shaly clay, with pyritic fossils (sub-zone of *Am.* [*Quenstedtoceras*] *lamberti.*)
	Am. ornatus [*Cosmoceras ornatum*]	Shales with pyritic fossils (sub-zone of *Am.* [*Cosmoceras*] *jason*).
KELLAWAYS BEDS.	*Am. calloviensis* [*Kepplerites calloviensis*]	Alternations of clays and sands with concretionary masses of calcareous sandstone (Kellaways Rock).
		Clay (Kellaways Clay)."*

In the northern part of the county the series has a thickness of between 400 and 500 ft. The upper beds alone occur at the surface, where they form the lower slopes of the southern side of the Thames Valley, between Buscot, near Lechlade, and South Hinksey, near Oxford. Being of little economic value, they are seldom worked, and the Geologists' Association seem to have seen no sections that call for notice here.

Corallian.—The Oxford Clay passes up into sandy beds which form the inferior, or Lower Calcareous Grit, division of the Corallian rocks. The sands are usually of a buff or brown tint; often exhibit oblique bedding, and are, in places, cemented into thin bands and detached "doggers" of calcareous oolitic sandstone, in which fossils are well preserved. Small pebbles of quartz, lydite, and other material are of common occurrence, and in the lower parts of this division, or stage, there are some beds of clay.

The upper stage, "which, on the whole, is more variable in character, comprises a series of limestones, oolitic, pisolitic, and shelly, with beds of coral-rag and occasional sandy and clayey beds.

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* See H. B. Woodward. *Mem. Geol. Survey*, "The Jurassic Rocks of Britain." vol. v, p. 8.

"The Corallian Beds may thus be grouped as follows:

UPPER CORALLIAN.	Upper Calcareous Grit, Upper Coral Rag and Ironstone . Coral Rag and Coralline Oolite .	Zone of *Ammonites* [*Perisphinctes*] *plicatilis*.
LOWER CORALLIAN.	Lower Calcareous Grit . .	Zone of *Ammonites perarmatus*. [*Aspid. perarmatum*."]*

In northern Berkshire, however, the Upper Calcareous Grit seems to be wanting, although it is present at Highworth, in the adjoining part of North Wiltshire. In the former district the Corallian varies from 60 to 100 or more feet in thickness. The outcrop-surface, extending across that part of Berkshire from Faringdon to Abingdon, is marked by a low hill-range of the cuesta type, which presents a distinct, and, in places, a steep scarp-face to the north, and falls away, very gently, into the White Horse Vale to the south.

The Coral Rag, and the highest beds of the Lower Calcareous Grit, are well exposed in shallow but extensive quarries around Marcham, Stanford, and Shellingford, to the west of Abingdon. The Association visited two quarries between Marcham and Shippon in 1892, when the more southern working showed:

		ft.	in.
"UPPER CORALLIAN (zone of *Ammonites* [*Perisphinctes*] *plicatilis*).	Red earthy soil.		
	5. Rubbly coral-rock and clay. . . .	4	0
	4. Rubbly oolite and marl, with fossil-bed at base, tapering away westwards . .	2	6
	3. Laminated clay and shelly sand . .	2	6
	2. Oolitic and shelly limestone, fossil-bed, tapering away eastwards, and replaced by rubble and pebbles of oolite, etc. 0 ft. 6 in. to	1	0
"LOWER CORALLIAN (Lower Calcareous Grit, or zone of *A. perarmatus* [*Aspidoceras perarmatum*]).	1. Sands with bands and doggers of calcareous sandstone	5	0

"From bed 3, *Ammonites* [*Perisphinctes*] *plicatilis*, *Belemnites abbreviatus*, *Lima pectiniformis*, *Ostrea gregaria*, *Trigonia*, *Echinobrissus scutatus*, *Pygaster*, and Lignite were obtained.

"The uppermost band of the Lower Calcareous Grit yielded *Natica marchamensis*, a form found also in bed 2.

"No examples of *Ammonites perarmatus* [*Asp. perarmatum*] were found, as the lower beds were not much worked.

"The President [the late J. F. Blake] remarked that some of the finest examples of that fossil were obtained from a pit farther north. These occurred generally in the form of casts, the shell and septa having been dissolved away, so that the casts of the chambers were in a loose form or linked together; hence the original name of '*Ammonites catena*.'"†

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* H. B. Woodward, *op. cit.*, p. 71.

† G. J. Hinde and H. B. Woodward, vol. xii, 1892, p. 331.

In the pit near the Lamb Inn, west of Kingston Bagpuize, the Upper Corallian Beds were seen to be "very variable in character, and there was evidence in rolled pebbles of oolite, some of which were bored by Lithodomi, and encrusted with Serpulæ, of reconstruction at more than one horizon and of pauses in deposition. The lowest bed presented a pisolitic aspect.

"The section has been described by Messrs. Blake and Hudleston.* The most fossiliferous portion was described by them as the '*Trigonia*-bed,' which comprises several layers of hard shelly limestone, partially oolitic, which merge downwards into the pisolitic bed, and yield *Ammonites* [*Perisphinctes*] *plicatilis, Belemnites abbreviatus, Trigonia meriani, Perna mytiloides, Gervillia aviculoides, Hinnites velatus, Trichites, Pecten fibrosus,* &c.

"The Lower Calcareous Grit beneath consisted of yellow sands with hard layers and nodular masses of calcareous sandstone. Altogether, the beds seen included Nos. 1, 2, 3, and perhaps the base of 4"—as noted in the section at Marcham.†

The Stanford and Shellingford sections, south-west of the above, were examined by the Association in 1907. A quarry at the western end of the former village shows:

"5. Dark loamy soil, in which prehistoric implements have been found—1½ ft.
4. Coral Rag—Broken corals and echinoderms, with the interstices filled with clay—4 ft.
3. Coralline Oolite—Hard, blue-hearted, flaggy rock with a few small pebbles of quartz, chert, and lydian stone, the flagstones alternating with occasional layers of coarse rubbly oolite—5 ft.
2. Coarse oolitic sand—6 inches, passing down into
1. Lower Calcareous Grit—Yellow sand, false-bedded in places, about 3 ft. shown. Water at bottom of quarry.

"The relative proportions of the hard and soft layers of Bed 3 vary somewhat when traced along the face of the quarry, but the composition and thickness of the other beds, of the coral bed in particular, remain very constant. The coral bed appears to form the subsoil over some extent of country hereabouts, and was formerly much used for road metal. . . ."‡

"Although [on the occasion of the above-mentioned visit] but little time was allowed for collecting, a fair number of fossils were obtained, including, from Bed 2, *Exogyra nana*, *Ostrea* (a medium-sized form), *Belemnites abbreviatus* (worn and covered with small oysters). From the hard crystalline matrix of Bed 3 specimens could only be extracted with difficulty, but *Gervillia aviculoides*, *Trigonia perlata*, and teeth of *Lepidotus maximus* were noted. The Corals in Bed 4 were chiefly belonging to the genera *Thecosmilia*, *Thamnastræa*, and *Isastræa*, in rather poor condition, associated with *Cidaris florigemma* (tests and spines), *Pseudodiadema versipora*, *Lithodomus inclusus*, *Littorina muricata*, and *Pecten articulatus*. No division between the palæontological zones could be detected owing to the lack of the zonal Ammonites in place, but a fragment of *A. perarmatus* [*Asp. perarmatum*] was found among the oolitic débris of Bed 3."[*]

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* *Quart. Journ. Geol. Soc.*, vol. xxxiii (1877), p. 304.
† Hinde and Woodward, vol. xii, 1892, p. 330.
‡ Ll. Treacher, vol. xx, 1907, pp. 115, 116.

The section seen in the quarry at the cross-roads about half-a-mile north-east of Shellingford is much the same as that at Stanford, "except that the quarry being situated higher up the dip-slope the bottom is free from water, and it can be worked to a greater depth. The lower sands are more current-bedded, and, like the overlying oolite, contain a good deal of wood. Bed 3 is rather thicker than at the last quarry, and there are more of the rubbly oolitic layers and much pisolite."[†]

"Additional fossils were *Pygaster umbrella*, *Echinobrissus scutatus*, *Belemnites nitidus*, *Myacites*, *Avicula*, *Pecten lens* and *Lima læviuscula*. In one part of the quarry the coral bed (4) is largely made up of stiff clay, a small piece of which, when washed, yielded many perfect specimens of *Thecidium ornatum*, spines of *Cidaris spinosa*, and Asteroid ossicles. Two claws of *Goniocheirus cristatus* and a tooth of *Pliosaurus* complete the list. No Ammonites were seen in place, but the workmen had put by specimens of *A. perarmatus* [*Aspidoceras perarmatum*], *A. cordatus* [*Cardioceras cordatum*], *A.* [*Perisphinctes*] *plicatilis*, and *A.* [*Perisphinctes*] *varicostatus*, all apparently from Bed 3."[‡]

The Kimeridge Clay "consists of dark grey and black shaly clay, with much selenite in places. The clay weathers brown at the surface. The beds are, as a rule, darker, and in mass more shaly, than the Oxford Clay, and the layers of septaria are more persistent and more frequent."[§] The shales are apt to be bituminous, and there are occasional bands of shaly limestone. Stratigraphical divisions are not well marked, but the following zones and sub-zones are recognisable:

" Zones.	Sub-Zones.
Ammonites biplex. [*i.e.*, *Olcostephanus pallasianus.*]	*Discina latissima.*
	Exogyra virgula.
Ammonites [*Amœboceras*] *alternans.*	*Ostrea deltoidea.*"[‖]

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[*] *Ibid., loc. cit.*
[†] *Ibid., loc. cit.*
[‡] *Ibid., loc. cit.*
[§] H. B. Woodward, *Mem. Geol. Survey*, " The Jurassic Rocks of Britain," vol. v p 151.
[‖] *Ibid.*, p. 152.

"Near Woolstone, south of Faringdon, Professor Hull reckoned that the Kimeridge Clay had a thickness of nearly 300 ft., but in the neighbourhood of Oxford the thickness does not exceed 100 ft."*

At the Chawley brickyard, north of Cumnor Hurst, the Association saw, in 1904,† a good section of the upper beds, which have there yielded, among other fossils, *Olcostephanus pallasianus*, *Modiola bipartita*, *Protocardia striatula*, *Thracia depressa*, and the greater part of a skeleton of the Iguanodon-like reptile *Camptosaurus prestwichi.*

The Portland Beds seem to be confined in Berkshire to the small outlier of Bourton, south of Shrivenham. They are there represented by chalky oolite and hard blue fossiliferous limestone, assigned to the Portland Sands by Sir A. Ramsay.‡

A thin bed of sandy limestone, containing *Astarte hartwellensis,* is seen beneath the Gault at Culham brickyard, on the Oxfordshire bank of the Thames below Abingdon.§

CRETACEOUS.

Between the Portland Beds and the rocks which overlie them in North Berks there is a stratigraphic hiatus of considerable importance. Excepting some local irregularities, the Oolitic strata were laid down in conformable succession, but in Cretaceous times these rocks (and with them some freshwater deposits of Wealden age, found in Oxfordshire and Buckinghamshire) were slightly flexed and faulted, and subsequently planed down by erosion, which may have been largely subaërial. It thus happens that the oldest member of the Cretaceous system so far recognised in Berkshire, namely, the marine Lower Greensand, rests upon the Jurassic rocks unconformably, and although in this county it seems to be generally in contact with some part of the Kimeridge Clay, it completely oversteps that formation, and passes on to the Corallian, at Faringdon.

The Lower Greensand (Aptian) is the most inconstant of the Secondary rocks found at the surface in Berkshire and Oxfordshire, even its outcrop lacking continuity.

About Sutton Courtenay, near Abingdon, on the east, it is represented by a small thickness of coarse, reddish, ferruginous, pebbly sands, which, at Culham, just across the Thames, have yielded *Exogyra sinuata.*||

North of Abingdon, outliers of the same sort of material

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* *Ibid.*, p. 166.

† Vol. xix, 1905, p. 57.

‡ "Geology of Parts of Wilts., etc.," Explanation of Sheet 34, *Mem. Geol. Survey* (1858), p. 27.

§ Vol. xviii, 1904, p. 303.

|| C. G. E. Dawkins. *Geol. Mag.*, dec. 5, vol. iii, 1906, p. 94, and *Proc. Geol. Assoc.*, vol. xviii, 1904, p. 300.

occur in the higher ground at Boars Hill, Cumnor Hurst, and Chawley, and are, at times, well exposed in the brickyard at the last-named place.*

South-west of Drayton the pebbly sands die out, and the Selbornian clay (Gault) appears to rest directly upon the Kimeridge clay along the line of the Great Western Railway between Steventon and Uffington Stations. North of Uffington Station, however, the sands emerge from beneath the Gault, and, thickening rapidly, run out northward in a sort of promontory, which rises well above the surrounding country in Furze Hill near Fernham, and terminates in a little plateau immediately to the south of Faringdon. To the east and to the west-south-west of Faringdon detached masses of the same formation occur in the hills of Faringdon Clump and Badbury, on the edge of the Corallian escarpment.

The late C. J. A. Meÿer, who was, in his day, the chief authority on the Faringdon Beds, recognised the following stratigraphical divisions: †

3. Sands, with chert and ironstone,
2. Red Gravel,
1. Sponge Gravel,

resting partly on the Kimeridge Clay, partly on the Corallian beds (see Figs. 35, 36).

Although the junction of the Sponge and Red Gravels is not visible, and the superposition of the latter upon the former has been questioned, the above grouping has been generally accepted by later observers. The total thickness of the Faringdon Beds is estimated at from 70 to 100 ft.

1. The Sponge Gravel, which Meÿer regarded as "unquestionably the oldest" of the local Cretaceous deposits, is well exposed, for a depth of about 30 ft., in Little Coxwell Pit‡ (*a* in sketch map, Fig. 35), and in a newer working called Bowler's Pit *(b)*, north-east and north of Little Coxwell village. It consists of coarse, buff to red-brown sand, containing many pebbles and sub-angular stones of quartz, dark siliceous rocks, shale, and limestone, mingled with a multitude of twig-like bryozoa, calcareous sponges, oysters, brachiopods, echinoderms, and other fossils; its aspect resembling that of the Coralline Crag of East Anglia.

Though friable on the whole, this gravelly sand is frequently cemented by calcite into doggers and bands of very hard sparry limestone; and it exhibits, in Little Coxwell Pit, a well-marked oblique bedding (inclined to the north-east), which simulates a dip.

Among the many indigenous organisms found in the Sponge

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* Vol. xix, 1905, p. 57.

† "Three Days at Faringdon," *Geologist*, vol. vii, 1864, p. 5.

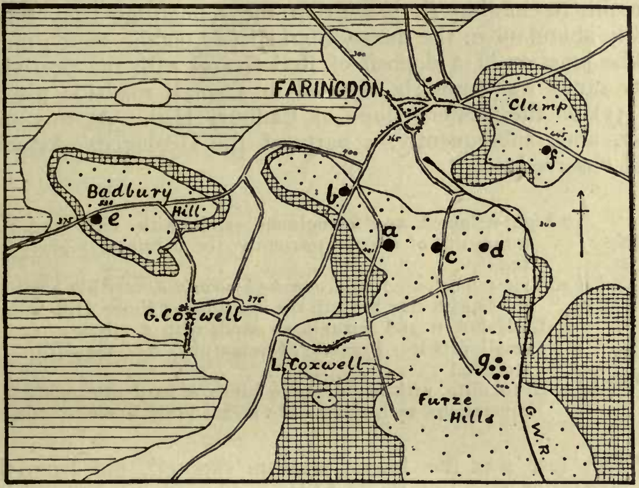
‡ So named on the 6-inch Ord. Map, Berks. viii. Known also as The Windmill, Panting's, Ballard's, Hickman's, and Purbrick's, Pit.

Gravel there may be mentioned: *Nautilus* sp. (large), *Lima parallela*, *Ostrea haliotoidea*, *Rhynchonella depressa*, *R. nuciformis*, *Terebratula sella*, *Entalophora*, *Domopora*, *Idmonea*, *Siphodictyum*, *Peltastes wrightii*, *Trematopygus davidsoni*, *Cidaris faringdonensis*, and the Sponges *Raphidonema faringdonense*, *R. contortum*, *Tremacystia anastomans*, *Peronella ramosa*, and *Corynella foraminosa*.

Lamellibranchs, other than the Ostreæ, are not common, and it is doubtful whether the single gasteropod *(Natica nodosa)* recorded by D. Sharpe* was found in the Sponge Gravel or in the Red Gravel.

FIG. 35.—SKETCH MAP SHOWING THE POSITIONS OF THE PRINCIPAL SECTIONS IN THE LOWER GREENSAND NEAR FARINGDON, BERKSHIRE.—*H. J. O. White*

Scale: 1 in. = 1 mile.



The Geological Boundaries are taken from the 1-inch Geological Survey Map, Sheets 13 and 34, Old Series.

Explanation of Shading.—Lower Greensand, dotted; Kimeridge Clay, cross-hatched; Corallian, unshaded; Oxfordian, parallel lines.

Bones and teeth of reptiles and fish, worn ammonites and belemnites, corals, etc., derived from the Kimeridge Clay, Corallian, and, probably, other formations, are abundant.

2. The Red Gravel consists of the same sort of materials as the Sponge Gravel, but it is more deeply stained by iron oxide—the prevailing tint being a rich, dark, brown-red. The sand also is coarser and the pebbles more numerous. The prin-

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* *Quart. Journ. Geol. Soc.* vol. x (1854), pp. 181, 193.

cipal sections are at Faringdon Pit *(c)**—about 20 ft. deep, and an unnamed pit *(d)*, about a quarter of a mile to the east. In both excavations, but particularly in the latter, the Red Gravel contains light-coloured bands resembling Sponge Gravel. According to Mr. Ll. Treacher,† the contemporary faunas of the two "Gravels" are nearly the same, the difference being mainly one of numerical proportion. Thus, *Trematopygus davidsoni* and the large *Nautilus*, mentioned above, are much more conspicuous in Faringdon Pit than in Little Coxwell Pit, where, until quite recently, they were supposed not to occur.‡ At least one form of gasteropod, a large *Pleurotomaria*,§ occurs in the Red Gravel, and seems to be fairly common in Faringdon Pit. Derived fossils are readily found, a belemnite resembling *B. nitidus* of the Kimeridge Clay being notably abundant in the quarry marked *(d)* on the sketch map.

The junction of a deposit of Red Gravel with the overlying cherty sands was formerly exposed in a small roadside pit *(e*, Fig. 35) on the western slope of Badbury Hill. At this spot Meÿer, and, subsequently, a party of the Geologists' Association,‖ observed:

		ft.
[SANDS WITH CHERT.]	"Light-coloured and ferruginous sand, with slabs and fragments of chert, apparently the débris of higher beds	14
	a. Fine ash-coloured sand, *regularly stratified*, very like the sands with clay beneath the ironstone of Furze Hill .	4
[RED GRAVEL.]	*b.* Dark brown and ferruginous sand, with a mixture of small pebbles, Bryozoa, Terebratulæ, &c., regularly stratified	4
	c. Ditto, ditto, with two or more bands of hard calcareous concretions, each about eight inches in thickness . .	5

"This last was the lowest stratum exposed, but from the appearance of the soil the pebbly sands extended somewhat lower."¶

Here, as at Faringdon Pit, the Red Gravel contained "*Rhynchonella nuciformis* in abundance, *R. latissima*, *R. depressa*, *Terebratella menardi* [*T. truncata*], *Terebratula tornacensis*, *T. depressa*, more rarely; and, in addition, a few specimens of *Terebratella oblonga*, Sow."**

The concretionary bands at the base of this section contained *Avicula rauliniana*, *Pecten rauliniana*, *P. orbicularis*, *Exogyra conica*, var., and *E. haliotoidea*, "shells which occur in the 'Bar-gate Stone' and 'Pebble Beds' of Godalming."* Sponge (or Red) Gravel was formerly to be seen in a pit at Fernham, two and a half miles south of Faringdon.

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* Otherwise Boutcher's, East, and Red Gravel, Pit.

† To whom the writer is much indebted for assistance in the preparation of this sketch of the Faringdon Beds.

‡ See remarks by E. C. Davey, "The Neocomian Sponges, etc., of Little Coxwell, near Faringdon" (London: Dulau and Co.) (not dated), p. 6.

§ Ll. Treacher, vol. xx, 1907, p. 120.

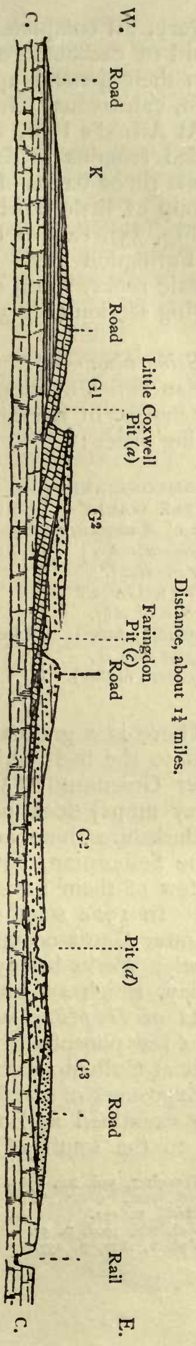
‖ Vol. iv, 1876, p. 549.

¶ Meÿer, *op. cit.*, pp. 6 and 7

** *Ibid.*, *op. cit.*, p. 7.

3. The sands with chert and ironstone form the higher part of the main Lower Greensand ridge of Fernham and Furze Hill; also the higher part of the Badbury mass, and, apparently, the whole of the outlier of Faringdon Clump. The character of the lowest layers of this division, at Badbury, has already been noticed. On the south-eastern slope of the Clump, and near the old brickyard, a small pit (*f*, Fig. 35), opened at a higher horizon, showed, in 1907, about 12 ft. of evenly-bedded light sand and slightly-glauconitic cherty sandstone, alternating with thin seams of grey laminated clay. Certain of the harder portions of the sandstone contain abundant "small spicules of siliceous sponges, like those figured by Dr. Hinde as belonging to the genus *Geodia*. A sample of the clayey material when washed yielded many pieces of shells, one small *Terebratula* and a fragment of the Bryozoan *Petalopora cunningtoni*,

FIG. 36.—SECTION ACROSS THE LOWER GREENSAND TRACT, SOUTH OF FARINGDON.—*A. J. Jukes-Browne.*



C. Corallian Beds. K. Kimeridge Clay. G^{1-3}. Lower Greensand (G^1. Sponge Gravel or Calcareous Conglomerate. G^2. Red Gravel or Ferruginous Conglomerate. G^3. Sands.)

First published in the *Proc. Geol. Assoc.*, vol. xii (1892), fig. 2, p. 332. With Mr. Jukes-Browne's permission, the title, legend and certain other explanatory portions of the figure have been altered to meet the requirements of the present article.

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* *Ibid., op. cit.,* p. 7.

Gregory, all completely silicified."[*] The beds here seem to be devoid of carbonate of lime, and form in this respect, as well as in their general appearance, a very marked contrast to the rough, calcareous "Gravels" of the lower divisions.

At Alfred's Hill, south of Furze Hill, the upper sands have yielded remains of Exogyra and a few other forms; and in bygone times bands of ironstone in this division were worked in a group of little bowl-shaped excavations known as Cole's Pits (*g*, Fig. 35), east of Little Coxwell. The inferred relations of the Faringdon Beds to one another, and to the underlying Jurassic rocks, south of Faringdon, are indicated in the accompanying section (Fig 36).

Selbornian.—Mr. Jukes-Browne has shown[†] that the Selbornian Series outcropping on the southern side of the Vale of Whitehorse, in Berkshire, comprises the following beds in descending order :

		ft.	
MALMSTONE AND UPPER GAULT (zone of *Ammonites* [*Schloenbachia*] *rostratus*).	Soft green sand . .	16 to 25	Approximate total thickness, 245 to 315 ft.
	Sandstone and Malmstone	35 to 80	
	Soft grey silty marl . .	50	
LOWER GAULT (zone of *Am.* [*Hoplites*] *interruptus* and *A.* [*Hoplites*] *lautus*).	Grey micaceous clay .	140 to 170	

There is a gradual passage upward from the Upper Gault marls to the beds which the Geological Survey has mapped as Upper Greensand, "and the line drawn between them [on the Survey maps] does not coincide with any special horizon."[‡] In Berkshire there are numerous small exposures of portions of the Selbornian, but they are lacking in general interest, and but few of them have been visited by the Geologists' Association. In 1904 some of the members were shown small patches of Lower Gault occupying hollows in the Lower Greensand at Chawley Works brickyard, near Cumnor.[§] From these masses of clay, which are much disturbed, Prof. Sollas obtained fragments of *Hoplites interruptus;* and during the Association's visit a few phosphatic nodules, of a type found at the base of the Gault at Culham, were noticed.

Exposures of the Upper Selbornian malmstone (or firestone) were examined at Lockinge Clump, near Wantage, in 1877,[||] and to the south of Castle Hill, near Little Wittenham, in

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[*] Treacher, vol. xx, 1907, p. 117.

[†] *Mem. Geol. Survey,* "The Cretaceous Rocks of Britain," vol. i, 1900, pp. 266 to 274.

[‡] *Ibid.*, p. 271.

[§] Vol. xix, 1905, p. 57.

[||] Vol. v, 1877, p. 137.

1903;[*] while in 1888 fossiliferous Greensand, at the top of the formation, was seen in the railway cutting north of Burghclere Station (Hants),[†] on the southern boundary of the area reviewed in the present article.

Chalk.—This important member of the Cretaceous System is most in evidence in the well-known upland of the Chilterns and the Berkshire Downs. Its full local thickness—about 800 ft.—is not developed beneath the summit or crest of the upland, for the higher beds of the formation are wanting there, and come in, gradually, on the southern or dip slope, the surface of which has, on the whole, a lower inclination than the planes of bedding.

To the south of the line of the Kennet-Thames, between Kintbury and Maidenhead, the Chalk disappears beneath the Eocene strata in the trough of the London Basin, to reappear in the Sydmonton Hills, farther south. In the railway cuttings through these hills, near Burghclere, the Association seem to have seen an almost complete section of the formation, in 1888.[‡]

The larger divisions of the Chalk which are usually recognised are the Lower, Middle, and Upper Chalk; the second and third, jointly, being the equivalent of the "White Chalk" of Dr. A. W. Rowe.

(a) The Lower Chalk (Cenomanian) of Berkshire and Oxfordshire varies in thickness from about 80 feet in the former county to 240 feet in the latter. It consists of :—

		ft.
2. Zone of *Holaster subglobosus.*	Grey marls with a bed of white chalk, sub-zone of *Actinocamax plenus*	2 to 3
	White and grey chalk	about 75
	Totternhoe stone	2
1. Zone of *Ammonites* [*Schloenbachia*] *varians.*	Marly and blocky chalk	about 135
	Glauconitic marl (" Chloritic marl ")	2 to 5

The good exposure of the Glauconitic Marl and part of the overlying beds (with *Schloenbachia varians, Turrilites bergeri,* and other fossils), to be seen in the lane leading northward from Lockinge to Wantage-road,[§] was most probably one of the sections visited by the Association during their excursion to Wantage and Hendred in 1877.[||]

A cutting on the Newbury and Didcot railway, near Chilton, visited in 1889,[¶] showed nearly 40 feet of chalk about the junction of the *H. subglobosus* and *A. varians* zones. The Totternhoe

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[*] Vol. xviii, 1904, p. 306.
[†] Vol. xi, 1889, p. xv.
[‡] Vol. xi, 1889, p. xv.
[§] A. J. Jukes-Browne, *Mem. Geol. Survey*, "The Cretaceous Rocks of Britain," vol. ii, 1903, p. 167.
[||] Vol. v, 1877, p. 137.
[¶] Vol. xi, 1889, p. lxxxiii.

Stone is there represented by 2 ft. of hard grey rock with many phosphatic nodules and fossils. Mr. Jukes-Browne observes that certain hard beds seen in this section contain sponge spicules and minute globules and aggregates of colloid silica.[*]

(b) The Middle Chalk (Turonian) of this part of the country has a thickness of 150 to 200 ft., made up as follows:—

		ft.
2. Zone of *Terebratulina.*	Pale greyish-white chalk, with thin seams of marl, and a few scattered flints near the top .	100 to 140
1. Zone of *Rhynchonella cuvieri.*	Nodular greyish and white chalk, with a hard band, (Melbourn Rock) about 8 ft. thick, at the base	60

A small opening in the Melbourn Rock on Blowingstone Hill, above Kingston Lisle,[†] appears to be the only section in the lower *(R. cuvieri)* zone observed by the Association in Berkshire.

Poorly-fossiliferous *Terebratulina*-chalk was seen in a small pit at Fognam Barn, north-west of Lambourn,[‡] in 1905, and in a quarry near East Woodhay (Hants) in 1902.[§] On three occasions[||] Association parties have inspected the highest beds of this zone in the sections at Henley Park (Oxon), or Medmenham (Bucks), in the Henley inlier; and portions of the same beds were seen near Mice Farm, West Wycombe, in 1907.[¶]

(c) The Upper Chalk (Senonian) of Berks, Oxon, and Bucks has an estimated maximum thickness of 420 ft., and comprises the following zones:—

			ft.
5. Zone of *Actinocamax quadratus.*	White chalk with flints (lowest parts alone represented)		50 ?
4. *Marsupites testudinarius.*	Ditto, with relatively few flints	*Marsupites*-band *Uintacrinus*-band	35 to 70
3. *Micraster cor-anguinum.*	Ditto, with many flints		220 ?
2. *Micraster cor-testudinarium.*	Ditto, nodular at base, many flints		50 ?
1. *Holaster planus.*	Greyish-white, lumpy and nodular chalk. Flints less abundant. Chalk Rock (sub-zone of *Heteroceras reussianum*) at or near base .		20 to 30

The Chalk Rock is worked for road metal in numerous shallow quarries near the summit of the Berkshire Downs, between Whitehorse Hill and East Ilsley; and one or more good sections near Cuckhamsley Knob or Barrow were examined by the Association in 1877[**], and again in 1889.[††] The Rock there is of the normal type: a hard, cream-coloured limestone with scattered grains of glauconite and layers of green-coated nodules. Its thickness is about 10 ft. In the highest layer of green nodules, at the top of the Rock, the characteristic fossils are (in places) abundant, and include *Heteroceras reussianum*, *Baculites bohemicus*, *Pachydiscus peramplus*, *Scaphites geinitzi*, *Cerithium cuckhamliense*, *Pleurotomaria perspectiva*, *Cuspidaria caudata*, *Trapezium trapezoidale*, and other forms.*

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[*] A. J. Jukes-Browne, *op. cit.*, vol., ii, p. 170.
[†] Vol. xix, 1905, p. 228.
[‡] *Ibid.*, p. 226.
[§] Vol. xvii, 1902, p. 394.
[||] Vol. xii, 1891, p. 204; vol. xvi, 1899, p. 253, and vol. xviii, 1904, p. 415,
[¶] Vol. xx, 1907, p. 101.
[**] Vol. v, 1877, p. 137, *et. seq.*
[††] Vol. xi, 1889, p. lxxxiv.

Equally clear but less fossiliferous sections of the same bed, and of the nodular beds above it, have been seen in the pits on the borders of the Middle Chalk inliers of Henley and Marlow, in the Thames Valley. The well-known pit at Henley Park,† and the quarries at Medmenham,‡ Remenham,§ and Marlow Waterworks‖ show the junction of the *Holaster planus* and *Micraster cor-testudinarium* zones; and the changes which the test-features of *Micraster* undergo with the changing horizon can be well studied in all these exposures.

Portions of the thick zone of *Micraster cor-anguinum*, which forms the uppermost stratum of the Chalk over the greater part of the Berkshire Downs and the Chilterns, have frequently been seen during the Association's excursions to the country west of London.

In the Taplow Court and Boxford sections these beds are slightly phosphatic, and contain one or more bands of hard chalk. A noteworthy fossil obtained from this zone at Boxford is a valve of *Exogyra sigmoidea*, a handsome species of rare occurrence in the English Chalk.

With the exception of the interesting development at Taplow, the zone of *Marsupites testudinarius* is confined to the south-western part of the Chalk country noticed in this article; the main mass of the zone lying to the south of the Kennet, between Savernake and Newbury, with a few detached and nearly-detached masses on the lower slopes of the Berkshire Downs, to the north of that river. The Association saw a small section in the lower, or *Uintacrinus*, sub-zone at Shaw Kiln, near Newbury, in 1879 and 1888¶; and another, in the *Marsupites*-band, on the eastern slope of Borough Hill, Winterbourne, in 1906.** In the Winterbourne section the *Marsupites*-chalk is flintless, and contains much phosphatic matter, approaching in these and other characters the better-known and more richly phosphatic deposit of Taplow.

The old quarry in which the last-mentioned deposit is exposed was visited in 1892,†† when most of the members of the party were able to secure specimens of the belemnoid *Actinocamax granulatus*,[*] which occurs in such extraordinary profusion in the upper part of the excavation. The section there is:

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* A. J. Jukes-Browne, *Mem. Geol. Survey*, "The Cretaceous Rocks of Britain," vol. iii, 1904, p. 204.

† Vol. xii, 1891, p. 204, and vol. xviii, 1904, p. 415.

‡ Vol. xvi, 1899, p. 253.

§ *Ibid.*, *loc. cit.*, and vol. xviii, 1904, p. 418.

‖ Vol. xix, 1905, p. 157.

¶ Vol. vi, 1879, p. 185, and vol. xi, 1889, p. xiii.

** Vol. xix, 1906, p. 352.

†† Vol. xii, 1892 p. 406.

			ft.
ZONE OF *Marsupites testudinarius.*	*Marsupites* band.	5. White chalk, very hard and slightly phosphatic at the top, becoming soft and strongly phosphatic at the base. *Act. granulatus*, *Ostrea lateralis* var. *striata*, *Scalaria* cf. *decorata*, etc.	16
		4. Brown chalk, richly phosphatic. *Marsupites*, *Act. granulatus*, *Echinocorys scutatus* (stunted pyramidate and sub-gibbous forms), *Ostrea vesicularis*, *O. wegmanniana*, etc.	8
	Uintacrinus band.	3. White chalk, with borings filled with brown chalk; hard at top, fossils scarce. *Echinocorys scutatus* (pyramidate form), etc.	16
		2. Brown chalk, richly phosphatic. *Uintacrinus*, *Actinocamax verus*, *Ostrea semiplana*, etc.	4
ZONE OF *Micraster cor-anguinum.*		1. White chalk, hard at top, soft below, and passing down into normal flinty chalk. Borings filled with brown chalk in the upper part. *Micraster cor-anguinum*, *Inoceramus cuvieri*, *Conulus albogalerus*, etc. . . . seen	17[†]

Teeth of fish are fairly abundant in the brown beds.

The only flints seen occur low down in bed (1). It is not improbable that the poorly-exposed upper part of bed (5) belongs to the zone of *Actinocamax quadratus*.

The zone of *Actinocamax quadratus* has, so far, been identified in only two places, namely, Borough Hill, west of Winterbourne, and Kintbury. In the Winterbourne pit, mentioned above, a few feet of slightly phosphatic and glauconitic chalk, with a thin rock-band at the base, occur between the *Marsupites*-beds and the soil. In the rock, and in the gritty chalk just above it, guards of *Act. granulatus* and tests of *Echinocorys scutatus* (of depressed pyramidate and ovate or sub-gibbous forms) are abundant, and with them occur *Offaster pillula*, and teeth of *Lamna* and other fish. In a pit at Laylands Green, south-east of Kintbury, the Association saw, in 1902,[‡] about 20 ft. of sparingly-flinty white chalk, which has since been referred, on ample evidence, to the lower part of the *Act. quadratus*-zone.[§]

Although the *Quadratus*-beds of Winterbourne and Kintbury have a very small areal range, there can be little doubt that they are the relics of a once widespread sheet of high-zonal Chalk, which was swept away by subaërial or marine agencies, or both, before the Eocene strata were deposited.

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[*] Called "Belemnitella quadrata" in the excursion report.

[†] Condensed from the account by H. J. O. White and Ll. Treacher, *Quart. Journ. Geol. Soc.*, vol. lxi, 1905, p. 461.

[‡] Vol. xvii, 1902, p. 388.

[§] Ll. Treacher and H. J. O. White, *Proc. Geol. Assoc.*, vol. xix, 1906, p. 389, and H. J. O. White, "Geology of the Country around Hungerford, etc.," *Mem. Geol. Survey*, 1907, p. 39.

EOCENE.

As a result of the wide-spread erosion mentioned above, the sands and clays of the Lower Eocene rest upon the Chalk unconformably. Occasionally rather pronounced, this discordance is, on the whole, of a gentle type, and in the area here discussed there appears to be no single section large enough to show it. A divergence of the bedding-planes of the Chalk from the basal surface of the Reading Beds has, however, been observed in a large excavation at Harefield,[*] about ten miles north-east of Taplow (see chapter i, p. 24).

The Reading Beds, which form the oldest member of the Eocene system found in Berkshire, have, by reason of the number and accessibility of exposures, received the "lion's share" of the Association's attention. The Series consists chiefly of coloured clays and sands, with which there are associated impersistent beds of pebbles, and—more rarely—of sub-angular gravel. At the base there is a loamy, glauconitic "bottom-bed," containing green-coated flints, bands of oyster-shells, and scattered sharks' teeth. This Bottom-Bed is a salt or brackish-water deposit; the rest of the series—unfossiliferous save for bits of lignite, silicified wood, and impressions of leaves—appears to be of fluviatile and lacustrine origin. The thickness of this formation varies from 60 feet, or less, to about 90 feet.

Brickyard sections at Reading have been visited by the Association on many occasions, the last excursion to the neighbourhood having been arranged in connection with the Geological Society's centenary celebration, in 1907.[†] Good exposures of the lowest beds and their junction with the Chalk were seen in the Waterloo and Coley Hill brickyards, south of the town, in 1876,[‡] and at Jesse's (otherwise Hill's or Grovelands) pit, south of Elm Lodge, in 1898. The last-named pit showed:

"DRIFT.		Gravel, very coarse, sub-angular, with many large quartzites	14 to 16 feet.
READING BEDS.		Sand, buff and white, much false-bedded .	8 to 10 feet.
	BOTTOM BED.	Clay, bluish grey, stratified .	2 to 2½ feet.
		Oyster-bed	6 to 12 inches.
		Clay, laminated, grey, with green sand . . .	1½ feet.
		Sand, green, with clay, and Oysters, green-coated flints at base	3 to 4 feet.

CHALK, with tubular holes formed by boring molluscs, the holes filled with green sand."[§]

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[*] W. Whitaker, *Mem. Geol. Survey*, "Geology of London," vol. i, 1889, p. 195.

[†] Vol. xx, 1907, p. 200.

[‡] Vol. iv, 1876, p. 519.

[§] J. H. Blake, vol. xv, p. 305.

"In this excavation an impersistent line (about ten yards in length) of sub-angular green-coated flints occurred in the lower part of the buff sands overlying the 'Bottom Bed.' . . The oysters mostly consisted of *Ostrea bellovacina*, Lam., many with both valves united. There were also a large number of oysters, identified by Messrs. Sharman and Newton as *Ostrea gryphovicina*, Wood, several good specimens of which were obtained on this occasion. The largest specimens of *Ostrea bellovacina*, with both valves united, occurred near the base of the 'Bottom Bed,' and continued upwards for about 3 to 4 feet in the glauconitic, olive-coloured green sand. Mr. Treacher obtained from the upper Oyster-bed in this pit the following fossils: *Corbula*, *Cytherea*, *Leda*, *Nucula*, *Modiola elegans* (?), Sow., *Tellina* (?), *Cerithium*, *Dentalium*, and *Odontaspis (Lamna) contortidens*, Ag."*—a small Woolwich-Beds fauna. It is of interest to note that the examples of mollusca from this bed preserved in Mr. Treacher's museum at Twyford are much below the normal size.

Extensive sections of the sands and mottled clays which overlie the Bottom Bed, and form the bulk of the Reading Series, have frequently been examined by Association parties in the Waterloo pits and in the neighbouring excavations of Katesgrove (Bob's Mount), while other good exposures have been inspected at Coley Hill; in the Mock Beggars brickyard at Earley, east of Reading; at Collier's Brick and Tile Works; Collier's Brick Kilns; Westwood Kiln and Norcot Kiln—the last four being situated to the south of the Oxford road, Reading. In most of these workings the junction with the overlying London Clay is, or was formerly, shown. In a part of Collier's Brick and Tile Works situated on the north side of the Rookery in Prospect Hill Park, there was seen, in 1898:

"LONDON CLAY.	Basement Bed, lower part only. . .	4 to 5 feet.
READING BEDS.	Mottled crimson, grey, and other variegated clays, about 30 to 40 ft. Buff and white sands, false-bedded in places (continuation of those seen in Mr. Jesse's pit) not bottomed . . .	about 10 ft. exposed."

In places the buff sands were cemented by calcareous matter into blocks that looked like sarsen-stone.†

The Waterloo pits afford the best local exposures of the Reading "leaf-beds"‡—a name given to a group of finely-bedded yellow sands and grey clays, in which the clays contain numerous impressions of the leaves and stems of plants doubtfully referable to *Laurus*, *Aralia*, *Salix*, *Acer*, and other genera. Here, and in other parts of Berkshire, the leaf-beds appear to be confined to the lower portion of the Reading Series.

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* J. H. Blake, vol. xv p. 305.

† *Ibid.*, p. 306.

‡ Vol. ix, 1885, p. 212; xiv, 1896, p. 411; xvii, 1902, p. 382; xx, 1907, p. 203.

In the country to the north and north-east of Reading the Association saw the leaf-beds well exposed at Knowl Hill Brickworks[*]; the mottled clays at the same place, at Rose Hill[†] near Caversham, and at Ruscombe[‡]; and the Bottom Bed at the entrances to underground chalk-quarries at Warren Row[§] and at Nettlebed.[||] At Nettlebed a number of clear sections of the beds forming the Lower Eocene outlier were seen in the pits below the windmill. Sections in other outliers on the Chiltern Hills have been visited at Lane End,[¶] Fawley,[**] and Penn.[††] The Reading Beds of Lane End are remarkable for containing a thick mass of flint-pebbles in their lower part, and irregular bands of flint and quartz gravel, with lumps of clay, in their upper layers, just below their contact with the overlying formation. Among other features of interest possessed by this outlier are the fine swallow-holes of Moor Common, and the dislocation of the *graben* type which has "keyed" a large block of Eocene strata into the Chalk, to the south-west of Lane End village.

West of Reading, the complete section of the Series—including "leaf" and "oyster beds"—shown at Shaw Kiln (Clay Hill),[‡‡] near Newbury, has twice received attention. Very coarse sands, near the middle of the Series, were seen in Winterbourne Wood[§§]; the upper beds and junction with the London Clay in the brickyards at Pebble Hill, Kintbury,[||||] and at Hollington,[¶¶] near East Woodhay; and, lastly, the contact of the Bottom Bed with the Chalk, on the Newbury and Winchester Railway, between Highclere and Burghclere Stations.[***]

The London Clay consists of stiff, dark blue-grey and brown clay, with layers of concretionary masses of impure limestone, known as cement-stones and septaria. The formation is of uniform character, except near the top, where it is sandy, and at the bottom, where there is a glauconitic and pebbly "Basement-Bed." Its thickness at Wokingham, on the south-east, is nearly 300 feet, but diminishes, north and north-westwards, to about 200 feet near Reading, to about 20 feet at Oare Common, north of Newbury, and, it is believed, to a few inches in Savernake Forest.

The sandy beds at the top and bottom are commonly dug for bricks, and are much more often exposed than the intervening clay. Good sections of the Basement-Bed have been examined by the Association, on many occasions, in the yards at Reading. In 1898 a pit at Norcot Kiln displayed:

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[*] Vol. xvii, 1902, p. 181.

[†] Vol. xix, 1905, p. 136.

[‡] Vol. xvii, 1902, p. 177.

[§] Vol. xvii, 1902, p. 180.

[||] Vol. xii, 1891, p. 206.

[¶] Vol. xvi, 1899, p. 252, and xx, 1907, p. 102.

[**] Vol. xviii, 1904, p. 416.

[††] Vol. xv, 1898, p. 312.

[‡‡] Vol. vi, 1879, p. 186, and xi, 1889, p. xiii.

[§§] Vol. xix, 1906, p. 351.

[||||] Vol. xvii, 1902, p. 389.

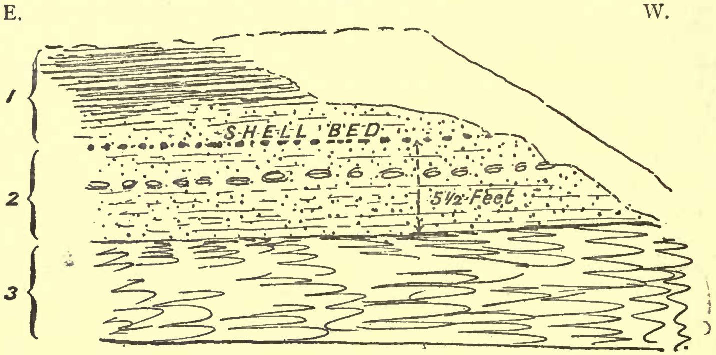
[¶¶] Vol. xvii, 1902, p. 394.

[***] Vol. xl, 1889, p. xv.

" Drift.		Gravel, pebbly; flints, quartz, many rounded quartzites derived from Triassic conglomerates, Lydian stone, etc.	about 6 ft.
London Clay.		Clay, mottled brown and grey	5 to 10 ft.
	Basement-Bed.	Sand and clay interstratified with white and black flint-pebbles in brown sand (in lower part), and casts of shells in ferruginous sand at and near base . . .	9 ft.
Reading Beds.		Clay, mottled crimson and grey	7 to 10 ft.
		Sands, buff and white	about 13 feet had been exposed."*

A diagram of the section formerly to be seen at the top of the Katesgrove pits in Bob's Mount is given in Fig. 37.†

Fig. 37.—Section in the Katesgrove Brickfield, Reading.—*H. W. Monckton.*



1. London Clay . . .	Dark brown and yellow clay passing down into—
2. Basement-Bed of the London Clay.	i. Brown sandy clay with a layer of shells. ii. Layer of nodules. iii. Sandy grey laminated clay.
3. Reading Beds . .	Mottled red and yellow clays.

From the shell-bed—still exposed in 1907—members of the Geologists' Association collected, on a former visit, the undermentioned fossils:

" *Odontaspis (Lamna)*
Aporrhais sowerbyi
Buccinum
Fusus errans
,, *speyeri*
Natica
Pleurotoma terebralis
Trochus
Cardium laytoni
Cytherea tenuistriata
Modiola elegans
Nucula bowerbankii
Ostrea bellovacina
Panopœa intermedia
Pectunculus brevirostris
Ditrupa plana." ‡

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* J. H. Blake, vol. xv, 1898, p. 307.
† H. W. Monckton, vol. xx, 1907, p. 205.
‡ J. H. Blake and H. W. Monckton, vol. xiv, 1896, p. 412.

At Mock Beggars Brickyard, near Earley, the Basement-Bed of the London Clay is of about the same thickness as at Bob's Mount, and is fossiliferous throughout. "Septarian nodules of argillaceous limestone, containing many shells and much lignite and iron pyrites, were observed in the bed, and the annelid *Ditrupa plana* was found to be exceedingly abundant in the lower part."*

Other sections of the Basement-Bed, resembling more or less closely those noticed above, have been inspected at Nettlebed† and Lane End,‡ to the north and north-east of Reading; while in the neighbourhood of Newbury, to the west and south-west, the same part of the formation was seen at Shaw Kiln,§ Donnington Kiln,|| Pebble Hill,¶ and Hollington.** At Lane End, Nettlebed, and Shaw there is an unconformity at the junction with the Reading Beds. On the other hand, at Hollington, near East Woodhay, where both the top and the bottom of the London Clay were shown in 1902, there appeared to be a passage into those beds.

Bagshot Series.—Of the Eocene strata overlying the London Clay, in the southern parts of the area under consideration, but little has been seen during the Association's excursions. The Lower Bagshot Beds, which rest, in most places conformably, upon the London Clay, consist of light-coloured sands with seams of pipe-clay and some thicker beds of grey and liver-coloured laminated clay. The sands are often micaceous and usually distinctly stratified, and contain—especially near the base of this division—a few pebbly layers, which here and there expand into thick banks of shingle. The full thickness of the Lower Bagshot is about 100 ft.

Sands of this age were seen in sections at Silchester†† and at Inkpen Common‡‡; and exposures of the pebble-beds were noticed at Pebble Hill, near Kintbury,§§ and at Hollington Brickworks.||||

The Middle Bagshot or Bracklesham Beds (about 40 ft. thick) are composed of brown and grey laminated clay in the upper part, and of yellow and olive-green loams and sands in the lower. The bedding is well marked, and pebbly layers are few and nowhere thick. In the green glauconitic loams near the middle of these beds marine mollusca and sharks' teeth are fairly common. The Association seems to have seen no sections worthy of notice in this area.

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* Blake and Monckton, vol. xiv, 1896, p. 414.
† Vol. xii, 1891, p. 206.
‡ Vol. xvi, 1899, p. 252; xx, 1907, p. 102.
§ Vol. vi, 1879, p. 185; vol. xi, 1889, p. xiii.
|| Vol. xi, 1889, p. xiv.
¶ Vol. xvii, 1902, p. 389.
** Vol. xvii, 1902, p. 395.
†† Vol. xvi, 1900, p. 514.
‡‡ Vol. xvii, 1902, p. 390.
§§ Vol. xvii, 1902, p. 389.
|||| Vol. xvii, 1902, p. 394.

The Upper Bagshots consist of buff and yellow sands, with little sign of bedding except at the base, where there is a thin, persistent bed of flint pebbles. The few fossils observed are rusty casts of marine mollusca belonging to species more or less characteristic of the Bartonian of Southern Hampshire.

A pit in slightly-fossiliferous sand of this age was shown to the Association, near West Street, Highclere, in 1888.* The small patch of sand in which it was opened is the westernmost outlier of the Upper Bagshot so far recognised in the London Basin.

PLIOCENE (?), PLEISTOCENE, AND HOLOCENE.

The Drifts, or Superficial Deposits of this area belong to the classes for which the Geological Survey has adopted the following names: Clay-with-Flints, Pebble Gravel, Plateau Gravel, Valley Gravel (including Brick-earth), and Alluvium (including Tufa).

The Clay-with-Flints is a brown to red-brown clay containing broken, little-worn flints and other material, both coarse and fine. It varies greatly in thickness and in composition. In most places it appears to be a mixture of the less soluble constituents of the Chalk with clay, sand, and stones derived from Eocene and later sediments formerly overlying that rock. No particular age can be assigned to it. Pipes or pot-holes filled with Clay-with-Flints have often been seen, in section, in chalk-pits visited by the Association, but this drift calls for no further notice here.

Pebble Gravel.—The deposits coloured as Pebble Gravel on the drift-maps of the Geological Survey are composed mainly of rounded stones in a sandy or loamy matrix. The pebbles are mostly of flint and quartz—the latter of small size—but other materials (*e.g.*, sub-angular and angular flints, bits of sandstone, pebbles of quartzite and of compact dark siliceous rocks) are almost always to be found, and in places are abundant.

This drift occurs in small scattered patches, resting unevenly upon the Lower Eocene outliers, and, less frequently, upon the Chalk, in the Chiltern Hills and in the eastern part of the Berkshire Downs. Near Henley, a few patches occur on the hills of Bowsey and Ashley, to the south of the Thames.

Deposits of the simpler, flint-and-quartz, type—usually the more remote from existing main lines of drainage—are probably merely subaërial accumulations of the coarser detritus of the Reading Beds and other Tertiary strata. Examples of such deposits have been seen by the Association at Nettlebed,† Tyler's Hill, near Penn,‡ Coleshill, near Amersham,§ and Fawley;||

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* Vol. xi, 1889, p. xiv.

† Vol. xii, 1891, p. 206.

‡ Vol. xv, 1898, p. 312.

§ Vol. xv, 1898, p. 312.

|| Vol. xviii, 1904, p. 416.

the last being situated close to the edge of the Thames Valley. The more complex gravels, of the kind seen on Bowsey Hill,* and in Common Wood, Streatley,† appear to be mixtures of the simpler, local, pebbly drift with some of the foreign siliceous material which is so largely represented in the quartzitic type of Plateau and Valley Gravel described below. The Bowsey gravel (and that on the neighbouring Ashley Hill) is thicker, and looks less disturbed, than any of the other deposits of the pebbly drift to be seen in this part of the country. It may well be a river-gravel of Pliocene age.

Plateau Gravel.—The beds bearing this name are coarse, gravelly drifts, which form or cover expanses of even, gently-inclined ground lying between the valleys. In this area they occur at various altitudes up to about 400 ft. above the level of principal streams in their vicinity.

Taking the character of their constituent stones as the basis of classification, the several deposits are found to fall into three divisions:

(1) In the first are gravels consisting mainly of flints, together with pieces of sarsen-sandstone, ironstone, and small pebbles of quartz. The Plateau (and other) Gravels of the Kennet basin are of this type. The best sections seen by the Association were at Snelsmore Common,‡ Basford Hill,§ Winterbourne Wood,|| all near Newbury; and at Inkpen¶ and Silchester** Commons. At the second and third localities a few eoliths were found in stratified gravel, about 150 ft. above the level of the Lambourn. The drift dug on Inkpen Common is a stiff clay, containing angular flints and blocks of sarsen, and exhibiting a sort of flow-structure. It may be mentioned that this flinty clay, which has a considerable development on the Eocene Beds to the south of the River Kennet, is sufficiently firm at Burghclere Common to allow loose gravel to be mined beneath it.

(2) The second type of Plateau Gravel contains, in addition to materials of the kinds present in the first, a great deal of chert and cherty sandstone, derived from the Lower Greensand of the Weald area, to the south-east. This drift characterises the country drained by the Loddon-Blackwater river-system, and by the small brooks running directly to the Thames farther east. It receives further notice in the article on the geology of the Hampshire area (chapter xii, page 292).

(3) The third type is more widely distributed than the first and second, and while resembling them in consisting to a large

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* Vol. xvii, 1902, p. 178.

† Vol. xiv, 1895, p. 176.

‡ Vol. xi, 1889, p. xiv.

§ Vol. xix, 1906, p. 351.

|| Vol. xix, 1906, p. 351.

¶ Vol. xvii, 1902, p. 390.

** Vol. xvi, 1900, p. 513.

extent of flints in various stages of attrition, differs from them in containing abundant pebbles and cobbles of red and grey quartzite, of tourmaline-grit, and of a variety of other siliceous rocks from the Midlands. Near the course of the Thames, between Wytham, near Oxford, and the gap in the Chalk Downs at Goring, gravel of this quartzitic type occurs in patches and small spreads on the summits of hills—such as Cunmor Hurst,[*] Boars Hill, and the Sinodun Hills[†]—which rise out of the Oxford plain. To the east of Goring, however, it forms broad, and often well-stratified, sheets, which overspread the Chalk on the lower slopes of the Chilterns, and cap some of the hills of Eocene strata on the opposite side of the Thames.

In the course of their excursions, members of the Geologists' Association have inspected these deposits at and near Caversham,[‡] at Bob's Mount,[§] and at Norcot on the Tilehurst plateau,[||] near Reading; at No Man's Hill and Fawley, near Henley;[¶] at Bockmer, above Medmenham;[**] at The Hockett, near Bisham,[††] and at Loudwater,[‡‡] south-east of High Wycombe.

From pits in this gravel north of Caversham (notably at Toots Farm) many Palæolithic tools have been obtained. At No Man's Hill and Benham's, north of Henley, gravels referred to the Plateau Series occur in well-marked terraces high up on the west side of the Thames Valley (see Fig. 38).[§§]

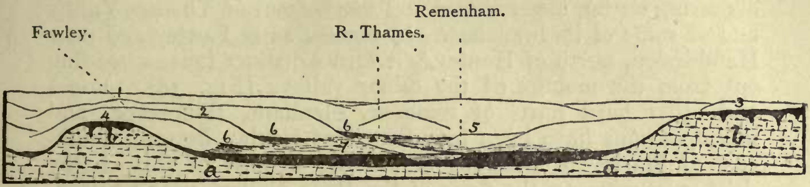
The presence of chert-stones, of the Loddon basin type, in many of the deposits of Plateau Gravel that border the valley of the Thames below (*i.e.*, down stream from) the embouchure of the River Loddon, near Twyford, is but one of several cogent reasons that can be adduced in support of the now generally-accepted theory that the Plateau Gravel, in the main, is of fluviatile origin. Such an origin, however, cannot, with any show of probability, be assigned to the tough, stony clay of Inkpen and Burghclere Commons. The present writer has suggested[||||] that this drift was formed under "extra-glacial" conditions; and he thinks that it is, in any case, an outcome of those processes of superficial creep and flow for which the attractive name "solifluction"[¶¶] has lately been invented.

The drifts of the Plateau-Gravel group are probably, for the most part, of Pleistocene age, although some may date back to the Newer Pliocene.

[*] Vol. xix, 1905, p. 57.
[†] Vol. xviii, 1904, p. 305.
[‡] Vol. ix, 1885, p. 209, vol. xix, 1905, p. 135, and vol. xx, 1907, p. 206.
[§] Vol. ix, 1885, p. 212, and vol. xiv, 1896, p. 412.
[||] Vol. x, 1888, p. 494, and vol. xvii, 1902, p. 382.
[¶] Vol. xii, 1891, p. 205, and vol. xviii, 1904, p. 414.
[**] Vol. xvi, 1899, p. 253.
[††] Vol. xv, 1897, p. 102.
[‡‡] Vol. xv, 1898, p. 311.
[§§] Vol. xviii, 1904, p. 415.
[||||] *Mem. Geol. Survey*, "Geology of Hungerford," etc., 1907, p. 92.
[¶¶] J. G. Andersson. *Journal of Geology* (Chicago), vol. xiv, 1906, p. 94.

The Valley Gravel, excepting some deposits interbedded with the Recent flood-loams, is of Pleistocene age. In its constituents it usually resembles the neighbouring spreads of Plateau Gravel, from which, indeed, its higher deposits are indistinguishable. The lower beds of Valley Gravel frequently contain mammalian remains and many fragments of Jurassic and Cretaceous limestones which are seldom preserved in the higher and older drifts. Valley Gravel, and its associated brick-earth, occurs in terraces of limited extent, and in sloping sheets, on the sides of the larger valleys. It occurs also in the bottoms of the valleys, and underlies much of the Holocene alluvium; rising, here and there, through the flood-loams in low "whale-back" shoals which—in their dimensions and in the height they attain above modern flood-limits—testify to the greater volume of the local streams in late Pleistocene times.

FIG. 38.—DIAGRAMMATIC VIEW AND SECTION OF THE THAMES VALLEY NORTH OF HENLEY.—*H. J. Osborne White.*



a. Middle Chalk.
b. Upper Chalk.
1. Pebble Gravel on Reading outlier, 520 feet O.D.
2. Terrace Gravel. Benham's, 400 feet.
3. Terrace Gravel. White Hill, 340 feet.
4. Terrace Gravel. No Man's Hill, 315 feet.
5. Terrace Gravel. Remenham, 180 feet.
6. Rubble Drift Fans.
7. Valley Gravel and Alluvium. [Level of the river here is a little above 100 feet O.D.]

Well-marked terraces are to be seen on the Berkshire bank of the Thames, between Maidenhead and Cookham,* and at Remenham, near Henley† (Fig. 38); also on both sides of the same river at Reading, and of the Kennet, at Newbury. Along the Thames above Reading terraces and sloping spreads of gravel are found at Cholsey and Culham, between Abingdon and Radley, and at Oxford. Gravel of a low-level terrace, near Culham Station, in the last-mentioned part of the valley, was examined by the Association in 1903.‡ Concretions of tufa and many worn fossils derived from the Jurassic rocks outcropping farther up the valley were observed in it.

Numerous palæoliths have been obtained from the gravel of a terrace about 75 ft. above the Thames south of Cookham,* and fine examples occur in a disturbed clayey gravel on the Eocene Beds at and around the Ruscombe brickyard;† while at Grovelands, in the western suburbs of Reading, stratified gravel of a terrace about 80 ft. above local river-level has yielded thousands of worked flints, together with remains of mammoth, rhinoceros, red deer, and other mammals.‡ The lower layers of the Grovelands gravel contain chalk-pebbles and derived fossils from the Oolites and the Lias. Between the Grovelands terrace and the Thames, and about 22 ft. above the latter, there is a small but thick deposit of coarse, chalky gravel in which teeth of hippopotamus have been found. Here implements are notably scarce.§

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* Vol. xv, 1897, p. 101, and vol. xix, 1905, p. 156.
† Vol. xii, 1891, p. 205, vol. xvi, 1899, p. 253, and vol. xviii, 1904, p. 418.
‡ Vol. xviii, 1904, p. 300.

Among the latest of the Pleistocene beds in the Berkshire area is a gravelly drift, consisting largely of chalk-rubble, and occurring on the lower slopes and the bottom of Thames Valley and of some of its branches. In places, as at Fawley and near Hambleden, north of Henley,‖ it forms distinct fans, spreading out from the mouths of the minor valleys (Fig. 38). Bones and other hard parts of reindeer, elephant, rhinoceros, and hippopotamus have been found in it at Hurley Bottom, south-east of Marlow.¶ Sections of another deposit of this chalky drift, occurring on the floor of the Pang Valley, near Chilton, were seen by the Association in 1889.** Here, remains of mammoth, rhinoceros, and reindeer have been obtained, together with land and fresh-water mollusca.††

In many of the combes that dissect the Berkshire Downs there is a similar drift containing large blocks of sarsen or grey-wether sandstone. At Ashdown Park, in one of the upper branches of the Lambourn Valley, hundreds of these boulders, encrusted with lichen, project through the turf.‡‡ The age of the sandy strata of which they are remnants is uncertain. A few miles distant, to the south-east, there are Eocene sands that look capable of bearing sarsens, but they contain none where they are exposed in pits.

Alluvium.—The Holocene or Recent deposits of the marshes and water-meadows bordering the larger streams consist chiefly of calcareous loams and clays, with subordinate beds of sand, gravel, shell-marl, and peat. Except in the stream-banks, which are usually too low to afford good sections, this drift is seldom exposed, and Association parties have had few opportunities to examine it.

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* Vol. xv, 1897, p. 101.

† Vol. xvii, 1901, p. 176.

‡ Vol. ix, 1885, p. 209; vol. xvii, 1902, p. 382. Note: The Grovelands deposit is grouped with the Plateau Gravels in the Geol. Survey Map, Reading district, Sheet 268.

§ Vol. xvii, 1902, p. 381.

‖ Vol. xviii, 1904, p. 417.

¶ *Mem. Geol. Survey*, "Geology of London," vol. i, p. 389.

** Vol. xi, 1889, p. lxxxiii.

†† A. J. Jukes-Browne, "Geology of Upton and Chilton," vol. xi, 1889, p. 198, and Prestwich, *Quart. Journ. Geol. Soc.*, vol. xxxviii, 1882, p. 127.

‡‡ Vol. xix, 1905, p. 226.

Fine gravel, containing a great deal of local Lower Greensand grit and Oolitic material, was seen in shallow pits at the Barley Mow Inn, opposite Clifton Hampden, in 1903;* and small sections of the peat and marl, so largely developed in the Kennet Valley, were examined in pits at Newbury in 1879.† The Alluvium at and near Newbury has yielded many implements and other "artifacts" of Neolithic, Bronze, and early Iron age; also human skulls and bones, teeth, or horns of elk, red-deer, roebuck, bison, mammoth, wolf, beaver, marten, badger, etc., together with fifty-two species of non-marine mollusca.‡ Remains of some of the above mammals were found also in the peaty clay of Plummery Ditch, Reading.§ Neolithic flakes were observed on the fields around the sarsen cromlech of Wayland Smith's Forge during the Association's visit to the Berkshire Downs in 1905.||

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* Vol. xviii, 1904, p. 304.
† Vol. vi, 1879, p. 188.
‡ "Geology of Hungerford," *Mem. Geol. Survey*, 1907, p. 107.
§ Vol. iv, 1876, p. 523.
|| Vol. xix, 1905, p. 227.

CHAPTER IX.

NORTH KENT AND ADJOINING PARTS OF SURREY.

By ARTHUR LEONARD LEACH.

INTRODUCTION.

NORTH KENT, as a geological area, forms with part of Surrey the northern limb of the Wealden anticline. It is therefore naturally limited on the south by the edge of the Chalk escarpment of the North Downs, and on the north by the Lower Thames and its estuary. Broadly speaking, this area comprises a range of Chalk uplands, largely overlain by ancient "drifts" of various kinds and ages, and flanked on the north by a broken belt of Eocene strata which stretch eastward from the main mass to the borders of the Isle of Thanet. The Eocene beds are partly masked by Pleistocene Drifts and fringed on the north by the alluvial deposits of the Thames and its tributaries. Near Guildford, where the Eocene border lies near the Chalk scarp, the Chalk forms a ridge barely half-a-mile in width, but, eastward, the Tertiary beds have been swept back by denudation to an irregular escarpment several miles north of the crest of the North Downs. The Chalk outcrop thus becomes 6 or 8 miles broad and so continues many miles in its eastward range towards Canterbury and Dover, where it increases to fully 10 miles. Except in the neighbourhood of the deep transverse valleys of the Darent and Medway, where the Tertiaries and Drifts have been much eroded, there are few large areas of bare Chalk, since much of the upland Chalk is covered by red Clay-with-flints and the associated brick-earths. The North Downs, ranging east-north-east from the Wey to the Medway and thence nearly south-east towards Dover, form the southern margin of the shallow synclinal trough known as the London Basin, within which lie the Eocene formations. A special feature of North Kent, as contrasted with north-east Surrey, is the great development of the older Eocene group of Lower London Tertiaries. In Surrey, west and north of Croydon, this group, even where present, is hidden by the London Clay, but in North Kent it is admirably exposed and exhibits its most characteristic structural variations. The full development of the Lower London Tertiary group distinguishes North Kent, geologically, from the adjoining area of Surrey. That the London Clay once spread uninterruptedly over all the Lower London Tertiaries and also over part, if not the whole, of the Wealden area, is generally accepted; but, being more susceptible to denudation than the lower group, it has disappeared from a great part of North Kent except in the form of outliers. Between Croydon and the Cray lies the main outcrop of the Lower London Tertiaries; farther east the enormous erosion around the Darent and the Medway has reduced even this group to the condition of a series of outliers varying from square miles to square yards in area. Subaerial denudation, continuing probably marine erosion, has also removed the Eocene beds from the higher parts of the Chalk dip-slope, leaving only a few scattered outliers high upon the North Downs, to indicate the former southerly extension of the Lower Tertiaries.

A consideration of the "solid" geology alone would suggest erroneous ideas of the surface features of North Kent, and particularly of the Chalk area. Much of the upland Chalk is covered by Clay-with-flints, which not only checks the development of the rounded hills and flowing contours of true Chalk areas, but supports thick woods and forms good pastures and fruit lands, thus imparting to the northern slope of the Downs much of the aspect of the Tertiary clay-lands. The striking change witnessed in passing from the pastures and woodlands of the clay-covered dip-slope to the dry, open, often treeless scarp overhanging the Vale of Holmesdale speaks eloquently of the scenic influence of a thin superficial deposit.

The feature formed by the higher clay-covered levels of the Chalk upland (rising south of the Tertiary escarpment) is conveniently termed the Kentish Plateau. It is deeply trenched by the Darent, the Medway, and the Stour, and grooved by many dry chalk valleys which run mainly in nearly parallel courses down the dip-slope, leaving a set of roughly parallel ridges still capped by Clay-with-flints. Between the Darent and the Medway, where the "plateau" is most characteristically developed, it rises to nearly 800 ft. O.D. Its deposits include not only Clay-with-flints and various Eocene and probably Pliocene outliers, but certain ancient Drifts—the Plateau-gravels, which form another special feature of the geology of North Kent. The far-reaching conclusions as to the antiquity of man, drawn from the discovery of palæolithic and eolithic implements in these gravels, which now cap the highest hills, but probably were originally deposited in river valleys, impart to the geology of North Kent an interest altogether unique.

A district so rich in geological interest has offered to the Geologists' Association abundant opportunities for field work. Soon after its foundation the Association visited the great Tertiary sections at Charlton and Lewisham, and during the half-century (1858-1908) more than 100 excursions have been arranged for the demonstration of the main geological features of the area. The Eocene sections at Charlton, Lewisham, Erith, Herne Bay, etc., have frequently been visited, but the Chalk, until recently, received somewhat scant attention. In the last few years the zonal features of the Surrey Chalk have been demonstrated,* but in Kent the inland Chalk, apart from the exposures in the Charlton, Gravesend, and Medway districts, still awaits zonal examination. The Pleistocene deposits of Erith, Crayford, Swanscombe, etc., occur in association with excellent Tertiary sections, and have frequently been examined, but few of the Plateau gravels have formed the object of an excursion, and this remark holds equally true with regard to more problematic deposits, such as Clay-with-flints, dry-valley gravels, and the infillings of "pipes" in the Chalk. Yet these superficial deposits of vast age and doubtful stratigraphical significance suggest some of the most interesting questions in the geology of the present day.

In geological literature North Kent has been almost exhaustively treated. Concerning the Tertiaries, for instance, Mr. Whitaker† remarks, "Our knowledge is comparatively perfect," and, it may be added, our knowledge of the composition and physical relations of the Drifts has now reached an equally advanced stage. The presentation of details of sections and lists of fossils, in this paper, seems therefore unnecessary, as these have been so often printed. A more useful purpose will, perhaps, be served by showing how the features of the various stratigraphical divisions have been demonstrated during the excursions, and then dealing a little more fully with some points of special interest. The deep-seated Cretaceous and Wealden rocks and the "underground plain of palæozoic rocks," which afford no opportunity for field-work,‡ and moreover demand for their discussion an area much greater than the North Kent "dip-slope," are omitted from consideration.

Geological Formations.

Superficial Deposits		Holocene alluvium. Pleistocene sands and gravels.
Beds of Doubtful Age		Sands, Gravels.
Pliocene.	Lenham Beds	Sands. Fossiliferous Ironstones.
Eocene.	Bagshot Beds	Sands.
	London Clay	Clay.
	Lower London Tertiaries	Blackheath and Oldhaven Beds. Woolwich and Reading Beds. Thanet Beds.
Chalk.		

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* "Excursion to Ashtead and Headley," *Proc. Geol. Assoc.*, vol. xix (1906), p. 347; "Excursion to Guildford," *ibid.*, vol. xx (1907), p. 174.

† "A Dozen Years of London Geology," *Proc. Geol. Assoc.*, vol. xvii (1902), p. 347.

‡ "Excursion to Plumstead and Crossness," *Proc. Geol. Assoc.*, vol. iii (1873), p. 268.

THE CHALK.

In recent years the chief interest of the Chalk has been in the recognition of the *Marsupites*-zone in the North Downs. The accidental discovery of fragments of *Marsupites* at Russell Hill, near Purley, in 1904, by two members of the Association,* gave a fresh impetus to the study of the zones of the Surrey chalk. Russell Hill lies 1½ miles south of the Tertiary escarpment. Since the *Marsupites*-zone had here escaped denudation, it became evident that it had not been swept away before the deposition of the Tertiaries,† and therefore it might reasonably be sought in pits nearer and within the Tertiary border. Mr. G. W. Young,‡ by systematic examination, demonstrated the presence of the *Marsupites*-zone, not only in outliers on the older Chalk, but also at many points along the Tertiary escarpment, proving conclusively that "the *Marsupites*-zone in its strictest sense does extend throughout the whole length of Surrey."

In North Kent the zones have been determined in the Charlton, East Wickham, Swanscombe, Gravesend, Rochester, and Medway districts.§ Along the Medway Valley all the zones have been determined from the *Micraster cor-anguinum*-zone to that of *Holaster planus*, but the Darent Valley still awaits complete examination. The tracing of the *Marsupites*-zone through Kent would link the Surrey with the Thanet exposures of this zone; it has been found at Keston and Farningham by Mr. G. E. Dibley, but the conditions favourable to its preservation farther east are not quite so good as in Surrey, and the great erosion of the Chalk in the vicinity of the Darent and Medway gaps will probably be found to make its recognition, as a continuous exposure, very difficult.

Chalk Mines.—The Geologists' Association has thrice visited the great galleries in the Chalk at Chiselhurst,‖ by means of which, instead of open quarries, Chalk has been extensively worked. The subject is hardly geological, but it has acquired a fictitious importance from the extraordinary theories recently advanced in connection with these old Chalk workings. It may be admitted that definite evidence of the first opening of the Chiselhurst galleries is wanting, but that is equally the case with hundreds of open quarries on the chalk hills. The galleries, "driven underground for quarrying purposes, consist of longitudinal and transverse workings, leaving great masses as pillars for the support of the roof" (*Report*, 1876). The chalk was used for lime-making, brick-making, and manure: the flints for building and for knapping into gun-flints. The reasons for driving galleries here instead of making open quarries are admirably stated in the PROCEEDINGS (*Report*, 1902). At the present time similar galleries are worked in the Chalk below the Tertiaries and Drift in the East Wickham valley.* There are at least three sets of workings, entered by vertical shafts about 90 ft. deep, and the total length of the galleries probably runs to at least 3 miles. All have been opened within the past fifty years, and the whole of the chalk has been used in brick-making. Somewhat similar galleries exist at Guildford and Northfleet.

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* *Proc. Geol. Assoc.*, vol. xix (1905), p. 196.

† *Mem. Geol. Survey*, "The Cretaceous Rocks of Britain," vol. iii, p. 179.

‡ *Proc. Geol. Assoc.*, vol. xix (1905), p. 188; *ibid.*, vol. xx (1908); p. 422.

§ "Excursion to East Wickham," *Proc. Geol. Assoc.*, vol. xix (1906), p. 341; "Excursion to Gravesend," *ibid.*, vol. xv (1898), p. 463; "Excursion to Northfleet," *ibid.*, vol. xiii (1894), p. 368; "Excursion to Rochester," *ibid.*, vol. xx (1907), p. 178. See also "Zonal features of the Chalk Pits in Rochester, Gravesend, and Croydon Areas," G. E. Dibley, *Proc. Geol. Assoc.*, vol. xvi (1900), p. 484.

‖ "Camden Park Galleries," *Proc. Geol. Assoc.*, vol. iii (1872), p. 114; "Camden Park Galleries," *ibid.*, vol. iv (1876), p. 498; "Excursion to . . . the Chiselhurst Caves," *ibid.*, vol. xvii (1902), p. 369. (Caves at the Bickley Arms).

Dene-holes.—These excavations, like the Chiselhurst galleries, but with greater justification, have aroused much curiosity, and their age and purpose have evoked much speculation. The Association has visited dene-holes at Hangman's Wood in Essex (see chapter ii, page 59), also at Bexley† and Stone, near Dartford. At Stone and at Abbey Wood‡ the cone of *débris* on the floor of the dene-hole was carefully searched, but no bones other than those of common domestic animals were found, and nothing indicative of great age or of any other purpose for the excavations than the quarrying of chalk for industrial uses. Amongst the many investigators of dene-holes opinion inclines more and more to the conclusion that dene-holes were not made for any other purpose than to obtain chalk.

EOCENE.

[A date, in brackets, in the text, indicates the year in which a particular feature was specially noted. Reports of excursions between 1860 and 1885 are summarised in the *Record of Excursions*. References, in full, to later Excursions are given in the footnotes.]

The Eocene sections of North Kent fall readily into four groups:

I.—The Herne Bay and Sheppey group.

II.—The Upnor and Higham group.

III.—Those of the main Lower London Tertiary outcrop, *e.g.*, Erith, Charlton, Chiselhurst.

IV.—The outliers high on the North Downs.

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* "Excursion to East Wickham" (1906), *Proc. Geol. Assoc.*, vol. xix, p. 341. In this report the depths assigned to the shafts are too great.

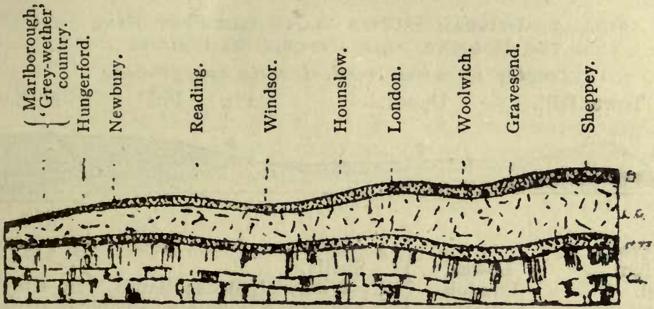
† "Excursion to the Dene-holes of Bexley" (1882), *Proc. Geol. Assoc.*, vol. vii, p. 400; "Excursion to Dartford and Stone" (1908), *ibid.*, vol. xx, p. 458.

‡ A dene-hole was thoroughly examined here in the summer of 1908, by the Woolwich Antiquarian Society.

I.—The bed of green-coated, unworn flints at the base of the Thanet Beds is not exposed at Reculvers, but it occurs at Pegwell Bay (1885) and in many sections throughout North Kent.

Near Herne Bay* and Reculvers the very fossiliferous clayey and marly marine sands of the *Thanet Beds* are not clearly separable from the *Woolwich Beds*, which they resemble structurally and palæontologically (1905). West of Oldhaven Gap false-bedded sands and sandstones 18 to 20 ft. thick constitute the *Oldhaven Beds*, the equivalents in this district of the Blackheath Pebble-beds. Towards Herne Bay the *London Clay* comes on, with a sandy and pebbly base resting irregularly on, and without passage into, the Oldhaven Beds, but the junction is marked better by "the sudden contrast of light buff sands and dark masses of clay" (1885). At Herne Bay the London Clay yields few fossils except pyritised wood. The scarcity of the fossil fruits, which abound in Sheppey, has been regarded as "evidence of the easterly flow of the Eocene river, by which these remains of vegetation were carried into the London Clay sea, the fruits becoming waterlogged and sinking nearer the estuary than the twigs and fragments of wood, which occur almost alone at Herne Bay" (1894).

FIG. 39.—IDEAL SECTION OF THE LONDON CLAY.—After *Prestwich.*



B. Bagshot Series.
L. C. London Clay.
Lr. Ts. Lower Tertiaries.
CH. Chalk.

In Sheppey† the *London Clay* is similar lithologically to the formation in the London area, but it differs palæontologically. The occurrence of the remains of turtles indicates the proximity of land, and the extraordinary abundance of plant remains "affords ground for concluding that near here a river emptied itself into the London Clay sea" (1875). Fossils are chiefly obtained from the nodules and masses of iron pyrites strewn along the beach by the waves. The large septarian nodules often contain beautiful crystals (1887) of Heavy Spar ($BaSO_4$).

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* *Record of Excursions*, 1863, 1870, 1875. "Excursion to Canterbury, Reculvers, etc." (1885), *Proc. Geol. Assoc.*, vol. ix, p. 168; "Excursion to Herne Bay" (1894), *ibid.*, vol. xiii, p. 375; "Excursion to the Isle of Thanet" (1905), *ibid.*, vol. xix, p. 149. See also *post* chapter x, p. 256.

† *Record*, 1861, 1868, 1875, 1881. "Excursion to Sheppey" (1887), *Proc. Geol. Assoc.*, vol. x, p. 194; "Excursion to Sheppey" (1898), *ibid.*, vol. xv, p. 459.

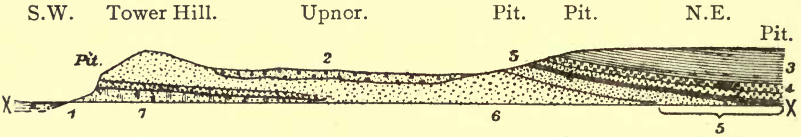
Mr. W. H. Shrubsole's remarkable discoveries of mineralised diatoms, pyritised radiolaria, reptilian and avian skulls, etc., are briefly described in the 1898 Report.

In Sheppey the London Clay approaches 480 ft. in thickness, but to the west it decreases, and a similar thinning is shown by the lower Eocene beds. This is indicated in the annexed diagram.

Near Eastchurch sands of *Lower Bagshot* age occur. In the cliff section between Hensbrook Gap and East End Lane they increase from a thin line to a thickness of 25 ft. of sands and loams (1887). Although a passage from the London Clay is seen in the sections in the London area, "a sharp line of demarcation has been observed in these cliff sections" (1898).

FIG. 40.—DIAGRAM SECTION ALONG THE LEFT BANK OF THE MEDWAY, NEAR UPNOR.—*W. Whitaker.*

Length, 1½ miles, vertical scale exaggerated.



X.—Sea-level.
1.—Alluvium.
2.—Gravel.
3.—London Clay.

Lower London Tertiaries.
4.—Oldhaven Beds; Sand, with Pebbles and Shells.
5.—Woolwich Beds; Sands, with Clay Shell-bed in the middle and Pebbles at bottom.
6.—Thanet Beds; Sand, the bottom part clayey and greenish.
7.—Chalk with Flints.

II.—Near Rochester* the *Thanet Beds* become almost unfossiliferous, and moreover are distinctly separated from the Woolwich series by a thin pebble bed (1891), thus differing from the Herne Bay type. An unusual feature occurred near Cliffe, where "the middle of the Thanet Sand showed signs of slight erosion or gentle current bedding" (1881). North of Upnor, pits near the church exhibit the complete Lower Tertiary sequence. In the *Oldhaven* and *Woolwich Beds* a curious seleniferous sand sometimes makes casts of shells. Selenite occurs abundantly in the *London Clay* in thin sheets along joint planes and in single crystals (1880, 1902).

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* *Record of Excursions*, "Upnor" (1880), "Higham" (1881); "Excursion to Higham" (1889), *Proc. Geol. Assoc.*, vol. xi, p. lxxii (Thames embankments): "Excursion to Upnor" (1891), *ibid*, vol. xii, p. 190; "Excursion to Frindsbury and Upnor" (1902), *ibid.*, vol. xvii p. 397.

III.—In the London district,* the Lower London Tertiaries differ from the East Kent type in the following respects:

(a) The *Blackheath Pebble-beds* replace the Oldhaven Beds.

(b) The *Woolwich Beds* become estuarine, not marine, in character, and are clearly divided from the Thanet Sand by a thin bed of pebbles.

(c) The *Thanet Sand* is almost unfossiliferous, and belongs, probably, to a lower division of the Thanet Beds than part of those of East Kent.

At Charlton, East Wickham, and Erith very fine sections still display the whole group, revealing their general *similarity* of structure, and also the variable nature of the middle member (Woolwich Beds). At Erith, in the Woolwich Beds, "traces of mottled clay and variegated strata occur among the higher members of the series, so that the Erith type forms a connecting link between the marine type of these strata seen around Canterbury and the more purely fluviatile strata represented by the beds at Reading" (1885).

In the East Wickham Valley (Fig. 41), between Plumstead Common and Bostal Heath, the fossiliferous estuarine clays and the thinly-bedded loams of the Woolwich Series are well exposed (1906), and evidence of an important change in physical conditions after their deposition is afforded by the deep "scoops" in which the Blackheath Pebble-beds lie. Opposite Hope Cottage the base of the Pebble-beds is only 12 feet above the top of the Thanet Sand, while, close by, in the Cemetery brickfield, nearly 50 feet of Woolwich Beds remain beneath the Blackheath Pebble-beds (1906). Scoops equally deep at Erith "seem to cut out locally nearly the whole of the Woolwich Series" (1885).

Charlton, with its fossiliferous Blackheath and Woolwich Beds, still remains a type-section of the Lower London Tertiaries. The pit now worked (Gilbert's, in Hanging Wood) was not the scene of the early excursions of the Association, but some of the old pits remain open, although the sections are much obscured.

From the Thanet Sand, fragile internal casts of two species of *Pholadomya* are occasionally obtained. Charlton thus presents the only general Lower London Tertiary section where all the members are fossiliferous. A "leaf-bed" in the Woolwich series has been noted here (1881), but it was formerly better

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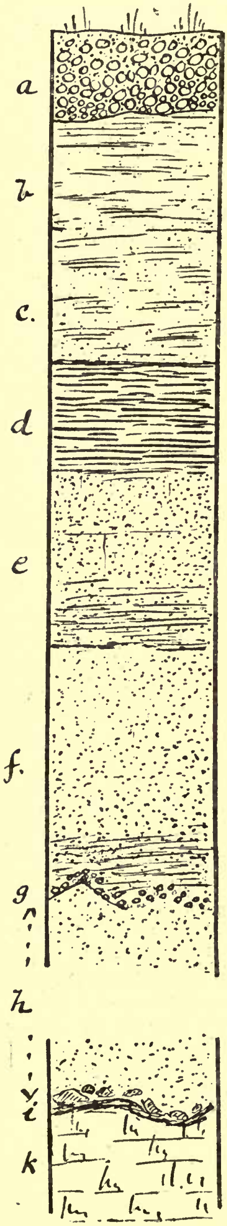
* *Record of Excursions*; Charlton, Lewisham, Blackheath, Greenwich, Westcombe Park, Plumstead, Erith, Crayford, Bromley, Chiselhurst Sundridge, St. Mary Cray have most of them been visited many times, and the Reports deal with both the Tertiary and the "Drift" geology. "Excursion to Loampit Hill, etc." (1888), *Proc. Geol. Assoc.*, vol. x, p. 501; "Excursion to Loampit Hill, etc." (1903) *ibid.*, vol. xviii, p. 161; "Excursion to Charlton" (1895), *ibid.*, vol. xiv, p. 111; "Excursion to Charlton" (1901), *ibid.*, vol. xvii, p. 182; "Excursion to Charlton and Erith" (1908), *ibid.*, vol. xx, p. 505; "Excursion to Plumstead" (1887), *ibid.*, vol. x, p. 191; "Excursion to East Wickham" (1906), *ibid.*, vol. xix, p. 341; "Excursion to Shooters Hill, etc." (1905), *ibid.*, vol. xix, p. 103; "Excursion to Erith and Crayford" (1885), *ibid.*, vol. ix, p. 213; "Excursion to Chiselhurst 1897 *ibid.*, vol. xv, p. 108.

FIG. 41.—SECTION IN THE "CEMETERY" BRICKFIELD, NEAR EAST WICKHAM, APRIL, 1906.—*A. L. Leach.*



a. (0-5 ft.). BLACKHEATH PEBBLE-BED.

WOOLWICH BEDS.

b. (5-7 ft.). Thinly and evenly bedded sands with thin clay partings.

c. (8 ft.). Light coloured sands with thin clay partings.

d. (6 ft.). Stiff dark clay with *Cyrena Ostrea*, etc.

e. (10 ft.). Fine light grey sand, very compact; in the lower part thin clay partings appear.

f. (13 ft.). Stiff greenish loam with a few widely scattered pebbles; the bottom part becomes more clayey.

g. (6 in.). Thin irregular bed of small rounded flint pebbles "splashed" into the underlying sand (=Base of Woolwich Beds).

h. (56 ft.). Fine white THANET SAND.

i. (6 in. to 1 ft.). "Bull head" bed or base of the Thanet sand, containing green coated flints and ferruginous clayey material.

k. CHALK.

developed at Loam-pit Hill. East of Elmstead (Chiselhurst) the conglomerates of the Blackheath Beds in Sundridge Rock-pit (1897) are very fossiliferous. A few quartzite pebbles have been found here (1897), and at Croydon by Dr. Hinde; they occur, also, at Worms Heath, Knockmill (1908), and Belvedere, and their derivation is one of the minor problems of the Blackheath Beds.

Good sections showing the junction of the Blackheath Beds and the London Clay are not often seen in north-west Kent. The London Clay being very uniform in structure and usually unfossiliferous, is of much less interest in the field than the variable Lower London Tertiaries. *Modiola* and *Nucula* were obtained at Shooters Hill (1905), and near Lewisham (1903) the Basement Bed of the London Clay yielded *Ditrupa*.

The prominence of the Lower London Tertiaries in north-west Kent arises from slight modifications of the general dip of the Chalk northwards from the escarpment. Although not usually exceeding 5° or 6°, this dip, if steadily maintained, would carry the Chalk far below O.D. along the line of the Lower Thames, and the river would run wholly in London Clay. But in the neighbourhood of Woolwich the base of the London Clay rises to about 200 O.D., and between Greenhithe and Tilbury the Thames cuts through a high ridge of Chalk. Lines of slight disturbance in the Chalk have been traced near Orpington,[*] Bromley, Chiselhurst, and Crayford; they indicate the existence of "a set of gentle and roughly-parallel waves running nearly east and west, by means of which the lower beds are kept at the surface to a greater extent than would otherwise be the case."[†]

One of the most interesting points brought out in reviewing the Tertiary sections is the presence of "planes of erosion" at various levels in the Eocene beds. The long sections in railway cuttings[‡] have afforded excellent opportunities for the examination of these irregularities. Usually between the Woolwich and Blackheath Beds an uneven junction appears. At Charlton there is but slight irregularity, but at Plumstead Common (1906) and Erith (1885) the Blackheath Beds rest in large "scoops" in the Woolwich clays and loams, which evidently were deeply trenched before the deposition of the Pebble-beds. The scouring action of estuarine currents, aided, perhaps, by slight tectonic movements, such as the initiation of the "rolls" in the underlying Chalk, may account for these "scoops." At Elmstead, towards the Chiselhurst end of the tunnel, more than 40 ft. of Blackheath Beds rest directly on the bottom-bed of the Woolwich Series, but towards the north, Woolwich Beds remain in considerable thickness at Grove Park, and also at Orpington on the south. The Woolwich clays and shell-beds are therefore completely cut out in less than half a mile.

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[*] "Excursion to Orpington" (1900), *Proc. Geol. Assoc.*, vol. xvi, p. 533.

[†] *Mem. Geol. Survey*, "Geology of London," vol. i, p. 483.

[‡] "Excursion to the cutting near Shortlands, etc." (1891), *Proc. Geol. Assoc.*, vol. xii, p. 92; "Excursion along the new railway from Blackheath to Bexley Heath" (1893), *ibid.*, vol. xiii, p. 152; "Excursion to the railway cutting south of Grove Park Station, S.E.R." (1900), *ibid.*, vol. xvi, p. 522; "Excursion to Grove Park, etc." (2nd visit), (1901), *ibid.*, vol. xvii, p. 136; "Excursion to S.E.R. Main line widening at Elmstead cutting," (3rd visit), (1902), *ibid.*, vol. xvii, p. 368; "Excursion to S.E.R. Main line widening, etc" (4th visit), (1902), *ibid.*, vol. xvii, p. 489; "Excursion to Orpington" (1900), *ibid.*, vol. xvi, p. 533; "Excursion to Orpington" (1901), *ibid.*, vol. xvii, p. 169.

A higher plane of erosion appeared at the base of the London Clay in the cutting for the Bexley Heath Railway (1893). Near Blackheath Park the London Clay rested unconformably not only upon Blackheath Beds, but also on an eroded surface of Woolwich Beds. This unusual feature is brought out in the diagram (Fig. 42), which shows, also, the irregular junction between the Blackheath and Woolwich Beds.

These "scoops" of Blackheath Pebbles into Woolwich Beds are of considerable interest in connection with the Tertiary outliers of the North Downs.

IV.—Along the north-western escarpment of the Eocene Tertiaries from Reading to Hertford, Woolwich Beds (Reading type) or London Clay rest directly on the Chalk, both Thanet and Blackheath Beds having thinned out farther east. This state of things occurs in numerous outliers in Berkshire and Hertfordshire, but the outliers of the North Downs present a different type. At Knockmill (727 ft. O.D.), Worms Heath (800 ft. O.D.), and Woldingham, patches of pebble-gravel, having the lithological character of Blackheath Pebble-beds, rest directly on the Chalk or on thin irregular layers of sand. Since they are unfossiliferous, their age is a matter of inference from their lithology. In explanation of the absence of the lower members of the Lower London Tertiary group, an overlap* of the Blackheath Beds has been suggested—an overlap which Mr. Jukes-Browne remarks "was probably a general southward overlap and overstep along a wide tract or front caused by a contemporary uplift of the Chalk over the Wealden area."† This overlap has been indicated more particularly in reference to the Addington and Shirley district, where Blackheath Beds rest on Thanet Sand. But at Sanderstead and Well Hill, to the south of the line of the Addington "overlap," Woolwich outliers remain, and at Punish, east of Knockmill, an outlier of Woolwich Beds rests on Thanet Sand near the edge of the escarpment. It is therefore by no means clear that any "overlap" along a wide front actually occurs. What is here seen appears to be due to "scooping" on a large scale, rather than to a gradual and regular advance of the Blackheath Beds beyond the edges of the

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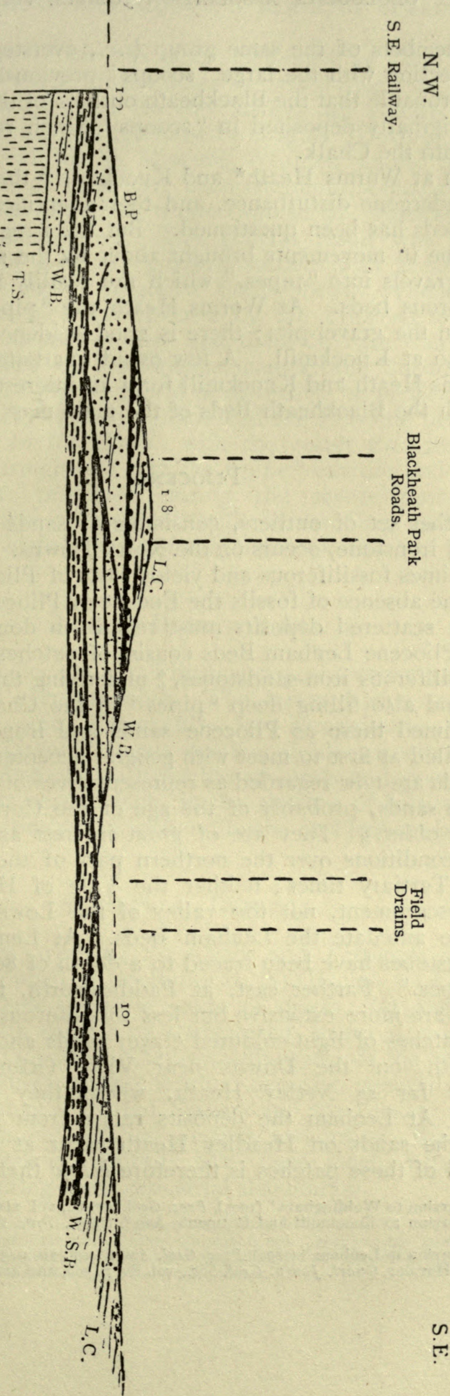
* *Mem. Geol. Survey*, "Geology of London," vol. i, p. 215.

† *Proc. Geol. Assoc.*, vol. xix, p. 287.

FIG. 42.—SECTION FROM RAILWAY JUNCTION ABOUT ¼ MILE EAST OF BLACKHEATH STATION TO A POINT S.W. OF LOWER KIDBROOKE FARM.—*T. V. Holmes.*



Figures 100, 118 show the height of the surface. L.C. London Clay. B.P. Blackheath Pebble Beds. W.B. Woolwich Beds.
W.S.B. Woolwich Shell Bed. T.S. Thanet Sand.

Scales: Horizontal, 6 inches=½ a mile; Vertical, ¼ of an inch=20 feet.

lower members of the same group (*i.e.*, overstep). Considered in connection with the large "scoops" previously mentioned, it seems probable that the Blackheath outliers of the North Downs were originally deposited in "scoops" which reached to some depth into the Chalk.

Both at Worms Heath* and Knockmill† the pebble-gravels have undergone disturbance, and their identification as Blackheath Beds has been questioned. But the irregularities appear to be due to movements brought about by the slow subsidence of the gravels into "pipes," which are readily formed beneath such porous beds. At Worms Heath the "pipes" are clearly shown in the gravel-pits; there is good evidence of their existence also at Knockmill. A few ovoid quartzite pebbles found at Worms Heath and Knockmill form an interesting lithological link with the Blackheath Beds of the main mass.

PLIOCENE.

Another set of outliers, consisting of sands and clays with layers of ironstone, occurs on the North Downs. The ironstone is sometimes fossiliferous and yields casts of Pliocene mollusca, but in the absence of fossils the Eocene or Pliocene age of some of these scattered deposits must remain in doubt. The well-known Pliocene Lenham Beds consist of patches of sand, clay, and fossiliferous iron-sandstones,‡ underlying the red clay-with-flints, and also filling deep "pipes" in the Chalk. Prestwich first claimed these as Pliocene sands and ironstones, but his views failed at first to meet with general acceptance. The Lenham Beds are now regarded as representatives of the continental Diestian sands, probably of the age of the Coralline Crag, or perhaps older.§ They are of great interest as indications of marine conditions over the northern part of the Wealden area in late Tertiary times; neither the Vale of Holmesdale, the Chalk escarpment, nor the valley of the Lower Thames can therefore antedate the Lenham Beds. At Lenham the sands and ironstones have been traced to a depth of 80 ft. in some of the "pipes." Farther east, at Paddlesworth, the deposits of this age are more extensive but less fossiliferous. Going westward, patches of light-coloured clayey sands and ironstones are met with on the Downs near Vigo, Otford, Merstham, etc., as far as Netley Heath, where they yielded fossils (1900). At Lenham the deposits range from 500 to 620 ft. O.D.; the sands on Headley Heath occur at 628 ft. O.D.; the level of these patches is therefore *below* that of the highest

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* "Excursion to Woldingham" (1905), *Proc. Geol. Assoc.*, vol. xix, p. 133.

† "Excursion to Knockmill and Cotman's Ash" (1908), *Proc. Geol. Assoc.*, vol. xx, p. 532.

‡ "Excursion to Lenham" (1892), *Proc. Geol. Assoc.*, vol. xii, p. 385.

§ F. W. Harmer, *Quart. Journ. Geol. Soc.*, vol. liv, p. 308, and *ante*, chap. iii, p. 87.

Eocene outliers. This has been explained as "due to their porous nature, which allows water to pass through and dissolve the Chalk,"* but as the Eocene outliers are equally porous, some additional explanation must be sought. During the denudation subsequent to the Miocene Wealden uplift, the waste of the Eocene beds must have been enormous, especially along the flank of the anticline, where sub-aerial agencies could operate with most effect. The general result was probably the formation of a deeply grooved surface with areas of bare Chalk, and upstanding ridges of Eocene beds. When, by subsidence, this surface was covered by the Pliocene Sea, Crag beds would be deposited here and there on bare Chalk below the level of some of the Eocene masses, and during a later period of uplift, "pipes" would most readily be formed beneath the porous pebbly Eocene outliers and the Pliocene beds which *rested directly on the Chalk,* with the result that these beds would subside irregularly into the "pipe" cavities and thus be, to some extent, protected during the severe post-Pliocene denudation which stripped the bulk of the Crag and Eocene beds from the higher levels of the North Downs.

Beds of Doubtful Age.

That mixed Eocene and Pliocene deposits occur in some of the "pipes" is very probable. The larger Eocene outliers—Worms Heath and Knockmill—are recognisable by their lithology; the larger Pliocene outliers yield characteristic fossils, but a number of small patches of sands and gravels † and "pipe" deposits occur which, in the absence of fossils, cannot be correlated strictly with either Eocene or Pliocene beds.

Superficial Deposits.

The deposits overlying the Chalk and Tertiaries may conveniently be grouped as (*a*) Residual, (*b*) Glacial, (*c*) Fluviatile, according to their probable mode of origin; (*b*) and (*c*) are essentially Drifts containing transported material foreign to the locality; (*a*) (of which Clay-with-flints affords the best example), while doubtless mainly residual deposits, generally contain notable proportions of drifted Tertiary and pre-Tertiary material. Probably no purely residual deposit remains on the Plateau where the superficial deposits have been much disturbed by movements resulting from sub-aërial denudation.

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* "Excursion to Netley Heath" (1900), *Proc. Geol. Assoc.*, vol. xvi, p. 524.

† Otford, Knockholt, Fair Seat, Ridley, Chipstead, etc. Many of the smaller patches are not marked on the Geological Survey maps, but they are recorded in "Geology of London Basin," *Mem. Geol. Survey*, vol. iv, pp. 336-342.

(a) Residual deposits.—Clay-with-flints, a stiff red clay containing abundant unworn Chalk-flints and, occasionally, Tertiary flint pebbles and fragments of older rocks, forms the "Plateau" above 400 ft. O.D. in the Medway and Darent areas, and descends to about 200 ft. O.D. near Sittingbourne. It lies very irregularly on the Chalk, and varies in thickness from a mere trace to 12 ft. or more. At Lenham it overlies part of the Pliocene deposits. Except by the presence of derivative pebbles and loams, it affords no evidence of transport, and, therefore, has been regarded as the residuum of the slow solution of the Chalk. Commenting upon its occurrence at Down, Darwin wrote, "During the dissolution of the Chalk a vast number of unrolled flints of all sizes has been left on the surface, and forms a bed of stiff red clay full of flints. . . ."* But the very small percentage of clay in chalk, and the occurrence of Tertiary pebbles and loamy material suggest that to the residue of the Chalk there have been added "the clayey and loamy wash from the Tertiary lands, and the remains of beds of that age left in pipes and hollows of the Chalk. The irregular-shaped flints would help in catching and holding the earthy matters, the iron would give a brownish-red colour to the whole, and the irregular decomposition of the Chalk would cause the resultant deposit of these actions to have a varying thickness and an irregular position."† This seems to provide an adequate explanation of the features shown by the Clay-with-flints on the Kentish "plateau." Its age remains doubtful; it sometimes underlies the Plateau-gravels, and must represent a long period of severe subaërial denudation, probably in part contemporary with glacial conditions north of the Thames Valley.

A residual Drift of pellety chalk occurs locally along the foot of the Chalk escarpment near Wrotham and elsewhere. It has been mapped as "Scarp Drift" by Mr. F. J. Bennett,‡ who regards it as the waste of the escarpment.

An equally problematic set of deposits, the "dry valley gravels," has been included by some observers, amongst the residual deposits. Mr. G. W. Young§ discusses the formation of "dry chalk valleys," and concludes that "these dry valleys are not valleys of corrasion|| at all, but are due to the simple dissolution of the chalk by surface water." He further remarks, "As might be expected on this theory the floor of these valleys is thickly covered with unrolled flints," and in some valleys thick masses of residual chalk drift ("Scarp drift") are found consisting of "small rounded grains of pure soft chalk, the evident

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* Quoted in Report of "Excursion to Down" (1892). *Proc. Geol. Assoc.*, vol. xii, p. 393.

† *Mem. Geol. Survey*, "Geology of London," vol. i, p. 282.

‡ "Excursion to Borough Green and Ightham" (1906), *Proc. Geol. Assoc.*, vol. xix, p. 462.

§ "On the Chalk area of North East Surrey" *Proc. Geol. Assoc.*, vol. xix, p. 191.

|| "Corrasion," a term introduced by Prof. J. W. Powell to denote the excavation or deepening of a river-channel as contrasted with the widening due to erosion of the banks.

result of this mode of weathering." The subject of dry valleys has been fully discussed in reference to other areas by Mr. Clement Reid[*] and Mr. Jukes-Browne;[†] it can only be treated very briefly here. In North Kent, whatever may be the case in other districts, the dry valleys are obviously connected with the present drainage system. In the Darent, Cray and Ravensbourne areas particularly, the upper dry valleys, trending in general to the north-north-east, open as tributaries into larger valleys,[‡] also now dry, which contain thick deposits of valley gravel and stratified brick-earths, and in these gravels rolled flints, Tertiary pebbles, and Lower Greensand chert and ironstone often are present in notable proportions. Since these upper dry valleys do not trench the chalk escarpment (except perhaps in the case of the Maplescombe Valley), this Lower Greensand material has probably been derived from the Southern Drift of the Plateau-gravels, and not directly from the former Wealden highlands; in either case, it indicates *transport* down the valleys. It is not easy, therefore, to see why *solution* should be regarded as the sole, or even the main, cause of these valleys. The transporting agency that moved and abraded the masses of chalk flints in the Cray Valley must have had a powerful *corrasive* action on the valley floor. Under present conditions the dry valleys are probably being slowly extended by the solvent action of rain-water and drainage from the clay-with-flints, and the unworn flints may represent the residue of this action, but the main lines of the valleys were probably sketched out, and their principal excavation took place, under conditions which no longer hold. The main objection to stream action in the formation of these valleys is based on the porosity of the chalk. Under present conditions the plateau and its dry valleys lie considerably above the saturation-level of the chalk, but any condition which would raise the level of the underground water, or make the chalk impermeable to rain-water, would permit the valleys to be eroded in a normal manner. Two conditions have been suggested:

1. An increase in the rainfall sufficient to keep the chalk permanently saturated.
2. A decrease in mean temperature sufficient usually to retain the interstitial moisture of the Chalk in a frozen state.

Probably during the glaciation of Central and Northern England these two conditions were from time to time alternately effective in North Kent, and the chalk uplands suffered "torrential denudation." Under such conditions the chalk would support only a scanty vegetation, its exposed surface would become deeply weathered, worn into ruts and broken into rubble by rain and frost, and from time to time the chalk and flint *dèbris* would drift down into the deepening valleys, and become mixed with the flints torn from the chalk by the corrasive action of the streams. With the post-glacial amelioration of the climate marked by decreased rainfall and increased temperature, the saturation-level would gradually sink below the valley floors, and the streams would cease to flow. During any temporary return of the first condition indicated above, stream-action in the valleys is renewed by the intermittent streams, called bournes, whenever the saturation-level rises to intersect the valley-floor. The rising-point of the bourne "gradually gets farther and farther up the valley as the underground water-level rises, until the greatest flow occurs, and then, as the flow decreases, the rise of the stream gets lower again with the decrease of the underground water-level, until at last the outflow ceases and the valley returns to its usual dry state."*

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[*] *Quart. Journn. Geol. Soc.*, vol. xliii (1887), p. 364.

[†] *Mem. Geol. Survey*, "Cretaceous Rocks of Britain." vol. iii, p. 418.

[‡] Hartley, Longfield, Fawkham, Maplescombe, Halstead (Upper Cray Valley).

(b) Glacial Drift.—Several observers have strongly upheld the existence of evidence of severe ice action in North Kent, but no deposits are yet generally accepted as the direct products of glacial action. A "white rubble," or "chalk-and-flint rubble," on the plateau above Otford was regarded by Prestwich† as "glacial waste" associated with that stage of valley erosion which preceded the formation of the low-level drifts in the valleys. Near Sepham Farm, where it underlies Clay-with-flints and extends into the dry valleys, it contains crushed chalk and sharply angular flints, with a few Tertiary pebbles and fragments of Lower Greensand chert. Its position *under* the Clay-with-flints is probably due to local slipping of the clay. Near Dartford, in a pit near the "Orange Tree," a similar drift lies beneath the Pleistocene gravels of the Darent.

Certain scratched flint flakes found in the Plateau Drifts were regarded by Prestwich and others as glacially striated, and a "striated drift" has recently been described in the PROCEEDINGS.‡

(c) Fluviatile Drifts.—That the Kentish plateau is deeply sculptured by rivers and that these rivers have left, at various base-levels of erosion, gravels which contain flint implements washed in from the contemporaneous land surfaces, are now generally accepted views, and the existence of man during the deposition of the highest valley-gravels is also generally admitted. Controversy arose when flint tools were stated to occur in a set of much older drifts—the Plateau gravels—not connected with the present drainage system, and which, if they are truly fluviatile drifts, must have been deposited by rivers with a gathering ground to the south over and beyond the area

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* "Excursion to the Croydon Bourne" (1904), *Proc. Geol. Assoc.*, vol. xviii, p. 388.

† "On the Age, Formation and Drift-stages of the Valley of the Darent," *Quart. Journ. Geol. Soc.*, vol. xlvii (1891), pp. 126-163.

‡ "Excursion to Well Hill," *Proc. Geol. Assoc.*, vol. xix, p. 235.

now occupied by the Vale of Holmesdale. Man must therefore have lived in Kent before the formation of the present Chalk escarpment, and before the excavation of the valley, 300 ft. deep, by which the Darent breaks through the North Downs. The position and composition of these gravels are now well known. They rest at various levels from 500 ft. O.D. up to nearly 900 ft. O.D. on the Clay-with-flints or on Tertiary outliers, and are composed mainly of (1) unstained angular flints, (2) much worn, very sub-angular, deep brown-stained flints, (3) Tertiary pebbles, (4) Oldbury stone, Lower Greensand chert and other detritus, and rare quartzite-pebbles.

Neolithic and Palæolithic implements occur *on* the gravel patches, and with them and at various depths *in* the Drifts, where palæoliths do not occur, certain much-worn, deeply-stained, rudely-worked flint implements are found. Prestwich, accepting the view of Mr. B. Harrison, that these rudely-chipped flints were shaped by man, carried this view to its logical conclusion and maintained that these implements (subsequently termed "eoliths") were deposited with and in the Drifts by streams flowing from the Wealden anticline, and that their mineral condition, identical with that of the unworked flints with which they are associated, indicated a derivation from still older Drifts. Since these Plateau gravels rest on Clay-with-flints—a deposit of great but doubtful age—their age can be fixed only in terms of denudation. They belong to the "Southern Drift," of Prestwich, and contain material (as above) which must have been derived from the Lower Greensand and Wealden areas by transport down a slope or river-valley from the outcrop of those formations. Between the Chalk and the Lower Greensand a great longitudinal valley, 300 ft. deep (Holmesdale, in part), now extends many miles east and west; the gravels must therefore have been deposited, and man must have lived in Kent, before the excavation of Holmesdale. The antiquity of man, as indicated by this enormous denudation, is undoubtedly very great; that he is pre-glacial is freely admitted, many even claim that he is older than the late-Pliocene. Whether the contemporaneous implements of the plateau gravels are termed "eoliths" or simply "older palæoliths" is of less importance than the recognition of their equality in age with the Drift from the ancient "Wealden Highlands."

In the controversy which centred about these plateau implements, it was urged that:

1. The chipping had been produced by purely natural agencies.
2. The "eoliths" did not occur *in* but *on* the gravels, and therefore might have been dropped by man long after

the deposition of the plateau gravels containing southern material.

The second objection could not be sustained after the discovery of "eoliths" at depths of 6 ft. to 8 ft. in undisturbed Plateau Drifts.

The question of the artificial origin of *some* eoliths is now practically settled in the affirmative, but, unfortunately, "eolithic chipping" is recognised by many collectors on flints which, to more critical eyes, show only the results of natural battering and pressure agencies. The use of such a term as "characteristic eolithic chipping" is to be deprecated, since it appears to be frequently impossible to distinguish between "eolithic" and natural chipping. Mr. Harrison remarks: "The chipping, although perhaps sufficiently regular to excite curiosity, does not warrant the inference that it is necessarily due to artificial causes."[*] There can be little doubt that "eolithic chipping" is only of value as a test of human handiwork when the chipped flints show "a tendency to approximate to certain defined types."

The eolithic implements of the plateau gravels are said to fall into groups of definite type, and, moreover, are distinguished from the palæoliths by their deep staining, which colours the natural and the artificial surfaces, and by their much-worn and rolled state. They are now very generally accepted as human implements deposited contemporaneously with the gravels by rivers flowing from the denuded dome of the Wealden anticline.[†]

At various levels below the plateau deposits lie the Pleistocene gravels of the present river-system. These have been very fully described in geological literature[‡] and at present are chiefly of interest from the attempts made to trace a progressive development in their implements. Messrs. Kennard and Hinton[§] divide the implements of the Lower Thames Valley into ten groups, but the absence of illustrations makes it difficult to judge how far the implements, considered individually or in groups, present features of progressive development which may be regarded as indications of man's corresponding advances in mechanical skill and intellectual development. If this omission could be remedied the value of the paper as a basis for future work in the Thames Valley, and as an aid to the correlation of its deposits with those of other rivers, would be greatly increased.

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[*] "An outline of the History of the Eolithic Implements" (1904), p. 9.

[†] "Excursion to St. Mary Cray, Well Hill. etc." (1874), *Proc. Geol. Assoc.*, vol. iv, p. 155; "Excursion to the Kentish Plateau" (1895), *ibid.*, vol. xiv, p. 196; "Excursion to Chelsfield and Well Hill" (1905), *ibid.*, vol. xix, p. 234; "Excursion to Borough Green and Ightham" (1906), *ibid.*. vol. xix, p. 460; for Excursions to Pleistocene gravels, see references to Tertiaries; also "Excursion to Crayford" (1890), *Proc. Geol. Assoc.*, vol. xi, p. cxliv: "Excursion to Swanscombe" (1890), *ibid.*, vol. xi, p. cxlv; "Excursion to Dartford" (1893), *ibid.*, vol. xiii, p. 70; "Excursion to Galley Hill" (1896), *ibid.*, vol. xiv, p. 305; "Excursion to Crayford" (1903), *ibid.*, vol. xviii, p. 165; "Excursion to Erith and Crayford" (1905), *ibid.*, vol. xix, p. 137; "Excursion to East Wickham, etc." (1906), *ibid.*, vol. xix. p. 341; "Excursion to Crayford and Dartford Heath" (1907), *ibid.*, vol. xx, p. 122; "Excursion to Knockmill," etc. (1908), *ibid.*, vol. xx, p. 532.

[‡] See "Superficial Deposits of Central and parts of Southern England," by Dr. A. E. Salter. *Proc. Geol. Assoc.*, vol. xix, pp. 1-56, where numerous references are given.

[§] "The Relative Ages of the Stone Implements of the Lower Thames Valley," *Proc. Geol. Assoc.*, vol. xix, p. 76.

In the "90 ft. Terrace" (Dartford Heath and Swanscombe) the gravels undergo a marked change in composition by the incoming of Jurassic, Triassic, and Carboniferous rocks and fossils. This foreign material associated with the rocks carried down from the "Southern Drift" of the North Downs is found in all the lower drifts of the Thames Valley.

A pebble of Lower Greensand chert lying side by side with a Carboniferous Limestone coral in the gravels of the Lower Thames, may epitomise the geological history of the gravels of North Kent. The one began its travels when the North Downs were part of the Wealden dome and rivers flowed over the Kentish plateau; the other entered the Upper Thames Valley, probably beneath the forefoot of a glacier, and gradually drifted down the stream during a period which, although almost inconceivably remote, is but as yesterday in comparison with the age of the pebble from the ancient Wealden uplands.

NOTE.—A general section of the Weald is given on page 435, chapter XIX, and two sections illustrating the formation of the Kentish Plateau will be found in vol. xix of our PROCEEDINGS, Plate I, illustrating a paper by Messrs. Kennard and M. Hinton.

CHAPTER X.

THE CHALK CLIFFS OF KENT AND SUSSEX, AND THE TERTIARY BEDS OF HERNE BAY.

By GEORGE WILLIAM YOUNG, F.G.S.

THE Weald of Kent, Surrey, and Sussex is encircled by an imposing range of chalk hills known as the North and South Downs. This great rampart is the escarpment of the Chalk formation, and it doubtless formerly extended across the area now occupied by the English Channel and joined the extreme eastern fragment which still exists to the north and south of Boulogne. The cliffs produced by the breaching of this rampart afford the geologist a convenient means of examining two complete sections of the Chalk formation as developed in the south-east of England. The Geologists' Association has made many excursions to these places, and references to all of them can be found scattered through the volumes of its PROCEEDINGS. Not only is this so, but the district about to be described forms the subject of the first of the splendid series of papers by Dr. A. W. Rowe on "The Zones of the White Chalk of the English Coast" which have appeared at intervals in the PROCEEDINGS during the last ten years. This account is so complete in every detail, so graphic in its language, and so lucid in its descriptions, that there would have been no necessity for a special chapter on this region in this volume were it not for the fact that the paper in question is out of print. The present account, therefore, is largely based on that paper, supplemented by my own observation and collecting.

As a convenient introduction, a short account will be given of the Tertiary coast-section in East Kent, which, together with the Chalk of Thanet, will be described in descending order, but the two main Chalk sections, which dip away on opposite sides from the anticlinal axis of the Weald, will both be described in ascending order so that the differences and resemblances may be the more easily contrasted.

HERNE BAY AND THE ISLE OF THANET.

Between the chalk of the North Downs and the Thames the Tertiary beds occupy a strip of undulating and mostly low-lying ground, the lower parts of which are overspread by the wide sheets of alluvium of the Medway, the Swale, and the Stour. The main road from Chatham to Sandwich roughly marks the junction of the two formations, and as far as Canterbury this is the line of the ancient Watling Street. The well-known coast section between Herne Bay and Reculvers has often been described, and several times visited by the Association. Owing to the gentle westerly dip the beds can be successively examined with great ease.*

At the end of the parade at Herne Bay the ground rises into cliffs composed of *London Clay.* Slipping is continually taking place, and great hollows of broken ground are formed. The clay contains many septarian nodules of varying sizes and much pyritized wood, quantities of which have been washed out of the cliffs and are mingled with the shingle on the beach. Many of the septaria show fucoid markings on the exterior. Occasionally the slipped masses of the clay show large patches with a well-marked slickensided surface, which, on drying, contracts with the well-known "starch structure" fractures, both features frequently being seen on the same slab.

The London Clay is succeeded by the *Oldhaven Beds,* so named by Mr. Whitaker, in 1866, after Oldhaven Gap (also called Bishopstone Ravine), the small chine which breaches the cliffs a little to the east of this point. They consist of compact fine drab-coloured sand, with frequent pockets and impersistent layers of fragile marine shells, mostly in fragments. In the cliff the junction with the London Clay is even and sharply defined, and can be easily followed by the contrast in colour of the beds, but where it rises from the beach the relationship is obscured by the slipping of the clay above. The junction with the Woolwich and Reading Beds, which underlie the Oldhaven Beds, is equally well defined by a remarkable bed of flint pebbles. This varies from 3 inches to 1 foot in thickness, and can be traced for a considerable distance as it gradually rises from the bottom to the top of the cliff. The pebbles composing it are well-rounded, and range up to 6 inches in length, and are remarkably black in colour, without any vestige of cortex. The latter feature is confirmative of Mr. Whitaker's suggestion† that this bed was accumulated at some distance from land, and therefore entirely submarine, as the pebbles in an ordinary tide-mark shingle beach usually show signs of atmospheric bleaching. Sharks' teeth are not uncommon in this pebble bed.

The *Woolwich and Reading Beds* also consist of compact sand, rather darker and greener in colour than the overlying beds, and contain numerous marine shells. They form the principal part of the cliff at Oldhaven Gap. The banks of this ravine differ greatly in character, the western being almost perpendicular, while the eastern is an uneven slope of slipped London Clay. The westerly dip, although slight, is probably the cause of this.

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* For reports of Excursions, see *Proc. Geol. Assoc.*, vol. i, p. 339; vol. iv, p. 254; vol. ix, p. 168; vol. xix, p. 149. See also *ante* chapter ix, p. 241.

† "Geology of the London Basin." *Mem. Geol. Surv.*, vol. iv, 1872, p. 240.

The *Thanet Sand* first appears in the cliff at this point, and forms the foreshore in front of the Gap; but the junction is not well defined, and Mr. Whitaker has remarked that "the passage between the two series in this part was caused by the incoming of higher beds in the Thanet series in East Kent, whereas near London the Woolwich Beds rested on a lower division of the Thanet Beds. He had always held that no one beginning to work at the Lower London Tertiaries in the far east of Kent would dream of dividing the Woolwich and the Thanet Beds; but, nevertheless, that division was clear enough in other parts."* The top part of the Thanet Sand contains a stony layer, consisting of large tabular masses about 8 inches thick, many of which show fucoid markings and occasionally casts of marine shells. The higher part of the shore between the Gap and Reculvers is thickly strewn with these slabs, which have been weathered out of the cliffs. The lower beds consist of dark green, muddy sands, containing enormous numbers of marine fossils. *Cyprina morrisii* is particularly abundant, and shows up like a vivid mosaic on the shore at low water. Unfortunately the shells are very fragile, and break almost at a touch. It is rather strange that they are not more damaged by the sea washing over them at every tide.

It is well known that there has been considerable erosion along this coast, and Reculvers has been cited as a measure of the amount, it being now at the edge of the cliff which is here protected with masonry, while in Henry VIII.'s time it is said to have been about half-a-mile inland.

The succeeding space of about three miles is occupied by the marshes of the filled-up channel of the Wantsum, the estuary which formerly bounded the Isle of Thanet on the west, and was navigable down to comparatively recent times. The northern branch of the Stour, with its ditch-like ramifications, is its present-day representative.

The *Chalk* of the Isle of Thanet is first encountered at the targets, but is very rubbly and much broken up. About a mile farther on, at Gore End, near Birchington, the headland called "The Minnies" exhibits the best examples to be found near London of the power of the sea in excavating caves and isolated stacks. All along this coast the chalk has strong vertical joints running north-west to south-east, and it is along these joints that the various caves have been eaten out.

For the next seven miles, past Westgate, Margate, and

* *Proc. Geol. Assoc.*, vol. ix, p. 170.

nearly to Kingsgate, the cliffs are formed of chalk of the *Marsupites*-zone, and afford the finest section of this zone in Britain. The chalk is white, very soft, and almost flintless. Fossils are abundant, generally well preserved, and easily cleaned; but before being placed in the cabinet they should be soaked in fresh water, changed daily for two or three weeks, in order to get rid of the salt. This applies to all chalk specimens from sea cliffs. About half-way up the cliffs is an ill-defined line of scattered nodular flints, called by Dr. Rowe the "Bedwell line," after Mr. F. A. Bedwell, its original discoverer. This is an important feature, as it roughly marks the junction of the *Marsupites* and *Uintacrinus*-bands. Below it, the detached ossicles of *Uintacrinus* are found scattered plentifully in the chalk, while above it *Marsupites* is equally common, with a mingling of the two forms at the junction. A very large ammonite, *A. leptophyllus,* is also characteristic of the *Uintacrinus*-band, but it is not so readily found as might be expected. The great majority of the specimens occur within 25 ft. of the "Bedwell line."

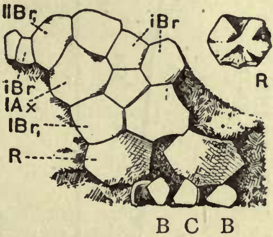


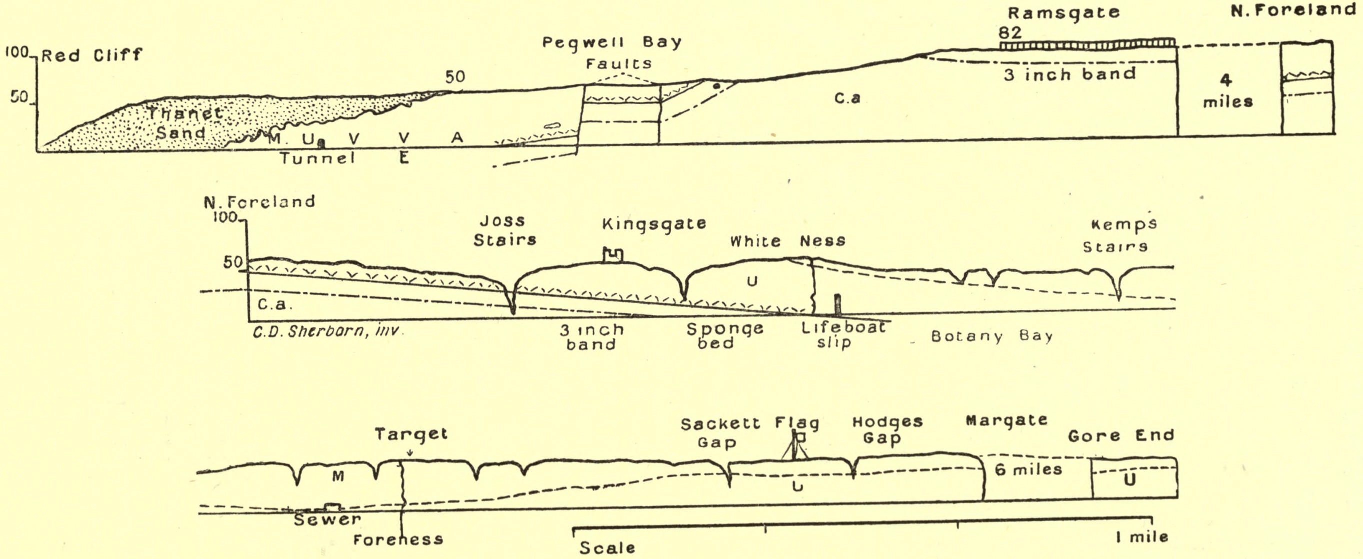
FIG. 43.—*Uintacrinus* from Margate; several plates in the natural position; natural size. C, centrale; B, basals; R, radials; I Br$_1$, first primibrach; I Ax, primaxil = second primibrach; II Br$_1$, first secundibrach; iBr, interbrachials. The detached plate is a radial, from Westgate, viewed on the inner surface. *Coll.* A. W. Rowe. Gilbert C. Chubb, *del.*; F. A. Bather, *dir.*

The cliff section (Fig. 44) runs practically along the strike, and it follows therefore that the accessible part of the cliffs is in the *Uintacrinus*-band. Foreness Point, however (two miles east of Margate), projects some ¼-mile from the general line of section, and this affords space for the northerly dip of the beds (possibly aided by a slight transverse syncline) to bring down the *Marsupites*-band to sea-level. Here the name-fossil can be found in abundance.

On nearing Kingsgate, we turn the north-east corner of the Island and the cliff section gradually changes from strike to dip, and we therefore come successively on lower and lower beds until at White Ness we find the "Barrois sponge-bed" rising from the shore. This marks the base of the *Marsupites*-zone. A little above it is a thin but very closely-packed layer of *Conulus* (=*Echinoconus*=*Galerites*) *conicus.*

We are now in the zone of *Micraster cor-anguinum*, and as the beds soon become horizontal we find that the whole of the cliffs from Kingsgate, past Broadstairs and Ramsgate, to Pegwell Bay, are cut in this zone, which is the lowest exposed in the

FIG. 44.—SECTION ALONG THE CLIFF-FACE BETWEEN RED CLIFF END (PEGWELL BAY) AND GORE END (BIRCHINGTON).—*C. Davies Sherborn.*



M. *Marsupites*-band } *Marsupites*-zone.
U. *Uintacrinus*-band }
C.a. *Micraster cor-anguinum*-zone.
V. Actinocamax verus.

A. ▭ Ammonites (*leptophyllus*-group).
〰〰〰〰 "Barrois Sponge Bed."
—·—·—·— Whitaker's "3-in. Band."
E. *Echinoconus*-Band.

Island. Near Dumpton Gap there are some small faults, with down-throw on the south, so that for a short distance there is room for a thin capping of the *Marsupites*-zone at the top of the cliff, but it is inaccessible. The chalk of the *Micraster coranguinum*-zone is as white, but more compact than that of the zone above, and nodular flint bands occur with great regularity, interspersed with tabular bands. One of the latter, "Whitaker's 3-inch band," stands out prominently 21 ft. below the Barrois sponge-bed, and can be recognised in the cliff nearly all the way to Pegwell Bay. Bedwell's columnar-band,* a peculiar cavernous layer of flint, rises from the shore at the North Foreland, 31 ft. below Whitaker's 3-inch band.

At Pegwell Bay the dip of the beds is southerly, and the *Marsupites*-zone comes in again, and in its turn is covered by Thanet Sands. The outcrop is short, owing to a higher dip than at Kingsgate, and this is aided by some small faults. The junction with the Thanet beds is not always clear, and the upper layers of chalk are somewhat rubbly.

At Pegwell Bay we reach the edge of the shallow synclinal fold in which the River Stour runs, once occupied by a wide estuary forming the southern boundary of the Isle of Thanet, but now filled by a level marsh, some four miles in width, over which the sluggish Stour wanders. Near its mouth, at Stonar Cut, the river makes an enormous loop, some seven miles in circuit, but only a furlong across at the neck.

Here Richborough Castle guarded the southern estuary, as Reculvers did the western one. Ebbsfleet, the reputed landing place of the Saxons, is close by, and the whole district is of great archæological interest.

The Dover Section: Folkestone to Walmer.

Starting from Copt Point, the southern horn of East Wear Bay, near Folkestone, Gault is found well exposed on the foreshore at low-water, and the profusion of brilliantly-coloured fossils is a continual attraction to the summer visitor. This is described in another part of this work (chapter XIX). Over the unctuous surface of the Gault the succeeding beds have slipped to an enormous extent, and produced an undercliff of broken ground, narrow in width but over three miles in length, and it is not until Shakespeare's Cliff is reached that the Chalk can be satisfactorily examined from the beach. This undercliff is called "The Warren." Above it towers Abbot's Cliff, which is the truncated end of the escarpment of the North Downs. The railway to Dover runs through it in cuttings and tunnels, and considerable shoring-up has been found necessary to preserve the stability of the line. A "halt" has recently been opened in about the centre of The Warren, and from it a wide, zig-zag path has been cut up the face of the cliff. When weathered this will probably afford a convenient means of examining the section. A very complete description of the beds of the Lower Chalk of this district has been given by the late Mr. Hilton Price,* and by Mr. Jukes-Browne,† so it will suffice to say here that the lower part of the cliffs overlooking The Warren consists of massive grey chalk, belonging to the zone of *Holaster subglobosus*, above which comes the yellowish-grey marl of the *Actinocamax plenus*-band. This band can readily be traced in the cliff, because it is succeeded by the basal "grit bed" of the zone of *Rhynchonella cuvieri*, which, from its superior hardness, frequently overhangs the marl band as a projecting cornice.

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* *Geol. Mag.* dec. 2, vol. i (1874), p. 19.

Shakespeare's Cliff presents an interesting section. The base can easily be worked at low tide, and at each end of the railway tunnel which pierces it, there is a convenient zig-zag up the cliff. That at the western end of the tunnel is close to the site of the first boring for coal in Kent and to the abandoned Channel Tunnel works. Here the lower part of the cliff is formed of the massive grey chalk of the *H. subglobosus*-zone, in which fossils are not very numerous, and the cliffs are also mostly wave-washed.

About 100 ft. up, the *A. plenus* marl band occurs and it can be readily traced for a considerable distance. Then comes the "grit-bed" of the base of the *R. cuvieri*-zone, a hard, gritty, buff-coloured bed of intensely nodular chalk, 32 ft. thick, which weathers with a very rough surface. In it fragments of shells abound, especially of *Inoceramus labiatus (mytiloides)*, and good specimens of *R. cuvieri* and *Discoidea dixoni* are not infrequent. The top of the first slope of the zig-zag coincides with the *A. plenus*-band, and nearly the whole of the second slope is cut in the "grit-bed." The remainder of the zone of *R. cuvieri*, about 40 ft., consists of hard chalk, still nodular, but less so than the grit-bed, and lighter in colour, with several marl bands.

The *Terebratulina gracilis*-zone commences a few feet below the bottom of the last long flight of steps, but there is no marked lithological feature at the junction. The chalk is white, and very marly, weathering with a smooth surface, on which the name-fossil shows up well. There are several marl seams, and some nodular bands. About 70 ft. of this zone is exposed here, and a very strong nodular flint line occurs just where the zig-zag reaches the top of the cliff.‡

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* Price, F. G. H. "On the beds between the Gault and Upper Chalk at Folkestone," *Quart. Journ. Geol. Soc.*, vol. xxxiii, p. 431.

† *Mem. Geol. Surv.*, "Cretaceous Rocks of Britain," vol. ii, p. 32.

‡ See also *Mem. Geol. Surv.*, "Cretaceous Rocks of Britain," vol. ii, p. 371, vol. iii, p. 135; Hill, W., "On the Upper and Lower Chalk of Dover, etc.," *Quart. Journ. Geol. Soc.*, vol. xlii, p. 232; Rowe, A. W., *Proc. Geol. Assoc.*, vol. xvii, p. 190.

Walking eastward, towards the highest point of Shakespeare's Cliff, the upper part of it is seen to consist of yellowish, very nodular chalk, containing many scattered flints, with two strong bands of flint in the lower portion. This flinty chalk is apparently about 40 ft. thick, and evidently belongs to the *Holaster planus*-zone.

Approximate thickness of the zones at the highest part of Shakespeare's Cliff (338 ft. O.D.):

Zone of *Holaster planus* about 40 feet.
,, ,, *Terebratulina gracilis* about 180 feet.
,, ,, *Rhynchonella cuvieri* about 70 feet.
,, ,, *Holaster subglobosus* about 50 feet.

At the east end of the tunnel a similar but smaller section can be examined. Owing to the dip of the beds, the *A. plenus* marl is here at shore level, while the grit band can be examined in the zig-zag and for about ¼-mile eastward at the foot of the cliffs behind the railway viaduct.

A short distance inland, chalk is exposed on the north flank of the South Military Road, which ascends to the Western Heights overlooking Dover. It is white, meagre, and rather soft, with strong flint lines from 2 ft. to 3 ft. apart. The surface, unfortunately, is very dirty, with a powdery crust, and fossils are not readily found; they indicate the lower part of the zone of *Micraster cor-anguinum*.

We now pass to the Eastern Heights, on the other side of Dover, where the Castle Hill presents a fine but inaccessible section from the zone of *T. gracilis* to that of *M. cor-anguinum*.

The zones of *T. gracilis* and *H. planus* can be examined along the sloping pathway up the cliff face overlooking the Harbour Extension. The junction of the two zones can readily be made out, but the Chalk-rock, in its true lithological sense, does not occur here.

The tunnel which formerly existed here has been removed in connection with the Harbour Extension works. These works prevent access to the base of the cliffs for some distance, and unless permission can be obtained to pass through the works, the shore north-east of Dover can only be reached by ascending to the top of the cliffs, walking past the Military Prison, and descending at Langdon Stairs, a zig-zag cut in the cliff face at the hollow called Langdon Hole, the last few feet of which is a rough scramble.

Dr. Rowe gives the following section, in ascending order, at Langdon Stairs*: "Below the lowest slope there are rough steps cut in the cliff, which are in the zone of *T. gracilis*, with the second open marl-band showing.

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* *Proc. Geol. Assoc.*, vol. xvi, p. 320.

"*1st slope.*—At the bottom of this slope is seen the first open marl band, with the two pairs of flint bands above and below it, marking the junction of the *T. gracilis* and *H. planus*-zones. The rest of the slope is in the zone of *H. planus*, and at the top of the slope, in the corner where it joins the second slope, is the junction of the zones of *H. planus* and *Micraster cor-testudinarium.*

"*2nd slope.*—All of this is in the zone of *M. cor-testudinarium.*

"*3rd slope.*—All of this is in the zone of *M. cor-testudinarium*, and the thin *M. cor-testudinarium*-tabular occurs in the lower part of the slope.

"*4th slope.*—All this is in the zone of *M. cor-testudinarium.*

"*5th slope.*—Shows the junction of the zones of *M. cor-testudinarium* and *M. cor-anguinum*; the basal *M. cor-anguinum*-tabular is one-fourth of the way down from the top of the slope.

"*6th slope.*—All of this is in the zone of *M. cor-anguinum.* The measurements taken of the beds on the shore were checked here, and agreed in all instances."

The cliffs from Langdon Stairs to Kingsdown present a very fine section, and as the gentle dip of the beds brings each zone in succession to the shore at a low angle, a wide collecting ground is offered to the observer. The whole distance can be traversed on foot when the tide is out. A falling tide should be selected, as long stretches of cliff are awash at high water, and it is very rough walking all the way. There is no way up the cliffs between Langdon Stairs and St. Margaret's Bay, nor between the latter and Old Stairs Bay.

Starting from Langdon Stairs, the top of the zone of *T. gracilis* is reached near the disused windlass shaft in Bantam Hole, where the white, marly chalk, poor in flint, gives place to yellowish nodular chalk, with abundant flint and more numerous fossils, of the zone of *H. planus.* The junction of the zones of *H. planus* and *M. cor-testudinarium* is not so easily made out, as these two zones have similar lithological characters, and it can only be located by careful collecting. Dr. Rowe gives the lower of a pair of strong nodular flint lines as the approximate junction. The *M. cor-testudinarium*-zone is full of fossils, which may be collected for some distance south of the southern horn of St. Margaret's Bay, where its junction with the overlying zone of *M. cor-anguinum* can be easily seen a few feet up the cliff. The upper zone consists of smooth, white, rather soft, chalk, with regular bands of nodular flints and occasional strong tabular bands. As is usual in the lower part of the zone of *M. cor-anguinum* it is very poor in fossils, so that the zoological contrast is as striking as the lithological.

The zone of *Micraster cor-anguinum* descends to the shore level at the north-east corner of St. Margaret's Bay, and extends thence, with a very slight dip, to Kingsdown, where the cliffs end. North of Leather Court Point (called on the new 1-inch map, Hope Point) the cliffs are based by a large grass-covered talus and a wide shingle beach. The sea is evidently encroaching here vigorously, for at this point the talus and shingle both terminate abruptly, and from here to St. Margaret's Bay the waves wash the base of the cliffs at every tide. The action is apparently rapid, for the mark of the removed talus can be seen on the cliff face, while the road which now terminates at Leather Court Point is shown on the new 1-inch map as extending all the way to St. Margaret's Bay, whereas every trace of it has now disappeared. Parts of the beach hereabout present a remarkable appearance. Strong, narrow ridges and deep grooves run out at right-angles from the base of the cliffs. Both ridges and grooves are about six inches wide, while the grooves are often a foot deep, as though the solid chalk had been scored with a gigantic rake.

No trace of the *Uintacrinus*-band—the lower part of the *Marsupites*-zone—can be found on the coast section, but it occurs in several places on higher ground a short distance inland, notably at Ringwold and Martin.* After passing Kingsdown no more chalk is seen until Pegwell Bay is reached, the intervening ground being occupied by the alluvial deposits of the Stour, flanked at Deal by a considerable spread of brick-earth.

THE SUSSEX SECTION: EASTBOURNE TO BRIGHTON.

At the eastern end of the South Downs, Eastbourne nestles under the escarpment in a position similar to that which Folkestone occupies at the eastern end of the North Downs. Near Eastbourne, however, the strike of the escarpment, which has had for some fifty miles a general easterly trend, suddenly turns nearly due south. The dip is not only changed in direction, but increased in amount, with the result that the truncated end, Beachy Head, shows in a short distance a complete sequence of the beds from the Gault up to the zone of *Micraster coranguinum*. The beds have been considerably faulted and squeezed, so that the piece of coast between Eastbourne and Birling Gap is of great geological interest, and by no means easy to unravel on a first traverse.

Mr. Clement Reid has put forward a bold hypothesis with regard to this disturbance. He remarks: "The effect of this disturbance is only felt for a very short distance inland, but eastward under the sea it apparently becomes more violent, though without submarine surveying it is impossible to say

* Rowe, A. W., *Geol. Mag.*, dec. 5, vol. v (1908), p. 74.

exactly what has happened. The disturbance is probably a broken unicline, like that of the Isle of Wight, with which it may be continuous. If this is the case, the Chalk of the South Downs, unlike that of the North Downs, is not connected across the Channel with France. Contrary to the accepted idea the escarpment curves round Beachy Head and turns to the west. The bed of this part of the English Channel may thus be a continuation of the wide plain of the Weald, and formed like the Weald by the erosion of the softer strata."* Until more definite evidence is forthcoming, I prefer the older explanation, and I think that Mr. Jukes-Browne's map shows the correct distribution of the formations.†

When examining Beachy Head a falling tide should be chosen, as there is no way up the cliffs between Cow Gap and Birling Gap, 3½ miles of heavy shingle walking. Starting along the shore from the southern end of Eastbourne parade, one proceeds for some distance along the strike of the beds. Below high-water mark, Gault and Upper Greensand are exposed on the shore in alternating strips, due to complicated over-thrusting. At the base of the cliffs the *Actinocamax plenus* marls can be well examined. Above are two old chalk pits; both are cut in the zones of *R. cuvieri* and *T. gracilis*, Gore Pit (the northern) showing much less of the higher zone than the much larger Holywell Pit (the southern). Farther on the Chalk marl and Chloritic marl can be examined near Cow Gap. The dip being high, we pass in rapid succession the zones of *H. subglobosus*, *R. cuvieri*, and *T. gracilis*. The Belemnite marls are of unusual thickness—nearly 20 ft.—but the other zones have been considerably affected by earth movements and estimates of their thickness differ.‡ Vertical and oblique fissures can be seen, some of which have strongly slickensided walls. The grit-bed, so strongly developed at the base of the *R. cuvieri*-zone at Dover, is poorly represented here. Unfortunately, the cliffs are so battered by the waves that collecting in these zones is an unprofitable task.

The base of the cliff immediately facing the *new* lighthouse on the shore belongs to the upper part of the *T. gracilis*-zone, and the junction with the succeeding zone of *H. planus* rises from the beach at a short distance farther on, the smooth, flintless chalk of the lower contrasting well with the nodular and flinty chalk of the upper zone. From here the magnificent cliffs of Beachy Head are seen to splendid advantage. Chalk has a great tendency to form vertical cliffs, and this, rising sheer to a height of 536 ft., is equalled by few headlands in impressiveness. Had Shakespeare's well-known lines been applied to this cliff, they could scarcely have been deemed an exaggeration.

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* "The Geology of the country around Eastbourne." *Mem. Geol. Surv.* (1898), p. 12.

† *Mem. Geol. Surv.*, "Cretaceous Rocks of Britain," vol. ii, frontispiece.

‡ Jukes-Browne, *op. cit.*, vol. ii, p. 397.

The junction of the zones of *H. planus* and *M. cor-testudinarium* can be found by measuring 80 yds. along the beach westward from the top of the *T. gracilis*-zone, and an iron-stained, vertical fissure, which runs from top to bottom of the cliff, helps to locate the spot.

The dip is now very much less, and the beds soon become nearly horizontal. For the next mile the base of the cliff is in the zone of *M. cor-testudinarium.*

It is well to remember that the inclination of the beds, as seen in the cliffs, is affected by the changes in the relation of the line of section to the direction of the dip. From Gore Pit to Beachy Head the section is roughly along the strike, for a short distance west of Beachy Head it is along the dip, and it then changes gradually, until, before Birling Gap is reached, it it again roughly along the strike, and continues so, with a local interruption at Seaford Head, all the way to Brighton. A glance at the geological map will help to explain this.

Two hundred yards before Beltout is reached there is a depression at the top of the cliff, and under it a thin tabular flint band rises from the shore. This is the junction of the zones of *M. cor-testudinarium* and *M. cor-anguinum.* Beltout is the old lighthouse on the top of the cliff, 1½ miles west of Beachy Head, and is now occupied as a private dwelling. Unfortunately, neither it nor the scoop in the cliff can be easily seen from the shore, but this thin tabular band can be identified by the help of another and much thicker one, which is prominent in the cliff face 60 ft. above it. From here to the Cuckmere the cliffs are cut in the zone of *M. cor-anguinum*, with cappings of the *Uintacrinus*-band on the tops of the four westernmost of the "Seven Sisters." The thick tabular band just mentioned descends gradually, and is seen to pass between the two small caves excavated one above the other in a vertical fissure 50 yds. west of Beltout. These two caves are known as Parson Darby's Hole. Farther west it passes under another small cave before it disappears beneath the shingle. Fifty feet above this thick tabular band there is another rather thinner one, with a yellow sponge-bed 15 ft. below it. Dr. Rowe calls this the "spurious tabular and sponge-bed." It misled Prof. Barrois, and caused him to place too much of this section in the *Marsupites*-zone. As I have pointed out elsewhere,* Barrois was similarly misled by a sponge-bed (possibly the same bed) in Surrey. In a fresh fall of chalk from the top of the cliff at Beltout the writer recently obtained the pyramidate form of *Echinocorys scutatus* and a well-preserved portion of *Ammonites leptophyllus*, both of which are indicative of the *Uintacrinus*-

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* *Proc. Geol. Assoc.*, vol. xx, p. 422.

band and support Dr. Rowe's suggestion that there may possibly be a capping of the *Marsupites*-zone at this spot.

From Birling Gap to the Cuckmere, two miles, is a good section in this zone, but the tide must be carefully watched. As in the case of so many of the small rivers on the south coast, the mouth of the Cuckmere has been diverted considerably to the east by the ever-shifting shingle.

At the western end of the last section the beds are rising, and the cliffs west of the Cuckmere are found to be of the *M. cor-testudinarium*-zone. This continues until Seaford Head is rounded, and then the beds are found to dip rapidly, and the higher zones come down successively until the zone of *A. quadratus* is reached. Beyond Hope Gap the cliffs are washed by the waves at high-water, consequently the junctions are hard to find. The section is too difficult to describe in a few words, and Dr. Rowe's account should be consulted. Caution should be observed in examining the cliffs, as falls of chalk sometimes happen. A lady was killed here by one in September, 1908.

A little beyond Seaford, the beds are again horizontal, and remain practically so for the next eight miles. Seaford Head, therefore, displays a structure which is almost that of a monocline, and Mr. J. V. Elsden has recently suggested that the Cuckmere runs in the line of a transverse fault (see chapter xi, p. 276).

In the cliffs from Newhaven to Brighton we have the longest British section of the zone of *Actinocamax quadratus*. It is easily accessible, and yields a characteristic fauna. This zone is generally variable as regards abundance of fossils, some beds being very rich and others very barren. *Cardiaster pillula* and a small gibbous form of *Echinocorys* are characteristic, and are more likely to be found than the name-fossil, which is very sporadic in its occurrence. *Ammonites leptophyllus* is not uncommon, but *Micraster* is conspicuous by its rarity. The chalk is moderately soft and white, but frequently iron-stained. It contains a large admixture of marly matter, and many marl bands which weather out as open seams. Nodular flint bands are common, but not so regular nor frequent as in the zone of *Micraster cor-anguinum*, while tabular flint occurs in enormous quantity in horizontal, and frequently in oblique sheets.

At only two places in this extensive section does any other zone appear. The first exception extends from Old Nore Point, one mile west of Newhaven Harbour, to the centre of Friar's Bay, about half-a-mile, in which space the *Marsupites*-zone is exposed at the base of the cliff, but this top part of the zone is not very fossiliferous, and the reefs on the shore yield a richer fauna. Another outcrop of the same zone commences a little west of the two stone groynes half-way between Rottingdean and Brighton. It rises gradually westward until at Kemp Town it extends about half-way up the cliff, which is here abruptly cut off by an ancient valley which is partly filled with Mantell's "Elephant" bed of Pleistocene age, against which the chalk cliff abuts almost vertically. Westward of Brighton the chalk dips down into the syncline of the Hampshire Basin and is no more seen on the coast.

Lithologically the *Marsupites*-zone of Sussex presents a great contrast to that of Thanet, for whereas in the latter area it is practically flintless, in Sussex it contains abundant flint, and cannot in this respect be distinguished from the zone above. Some of the fossils also vary in distribution. The Ammonites are mostly confined to the *Uintacrinus*-band in Thanet, but are found in the *Marsupites*-band and *A. quadratus*-zone in Sussex, while *Act. verus* is common in the *Uintacrinus*-band in Thanet, but absent in Sussex.[*]

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[*] Reference should be made to the following works Barrois, C., "Recherches sur le terrain crétacé supérieur de l'Angleterre et d'Irlande" *Mem. Soc. Geol. Nord.* (1876); Bedwell, F. A., "Ammonite Zones in the Isle of Thanet," *Proc. Geol. Assoc.*, vol. iii, p. 217, and *Geol. Mag.*, dec. 2, vol. i (1874), p. 16; Gardner, J. Starkie, "The Lower Eocene Section between Reculvers and Herne Bay," *Quart. Journ. Geol. Soc.*, vol. xxxix, p. 197; Jukes-Browne, A. J., *Mem. Geol. Surv.*, "The Cretaceous Rocks of Britain," vols. ii and iii; Rowe, A. W., "The Zones of the White Chalk of the English Coast, part 1, Kent and Sussex," *Proc. Geol. Assoc.*, vol. xvi, p. 289; Whitaker, W., "On the Chalk of the Isle of Thanet," *Quart. Journ. Geol. Soc.*, vol. xxi, p. 395, "Geology of the London Basin," *Mem. Geol. Surv.*, vol. iv (1872).

CHAPTER XI.

THE TERTIARY AND POST-TERTIARY DEPOSITS OF THE SUSSEX COAST.

By J. V. ELSDEN, B.Sc., F.G.S.

The Tertiary Beds.

THE post-Cretaceous deposits of the Sussex coast have been examined by the Association on several occasions. In 1866 Brighton was visited, and in 1887 Messrs. Henry Willett and W. Topley conducted an Easter excursion to Brighton, Newhaven, and Seaford, Mr. Whitaker having on the preceding days taken a party to Bognor, Pagham, and Selsey Bill. More recently, in 1904, Selsey and Chichester were visited, and in 1907 there was an excursion to Seaford and Newhaven.

The Tertiary Beds.—In spite of the flat appearance of the Sussex coastal plain, the Tertiary strata lie in a well-defined synclinal fold, which is an extension of the Hampshire Basin, but the outcrops are almost everywhere covered by drift, and our knowledge of the thickness of the beds is dependent upon well borings. The main interest for our present purpose centres round three localities, viz., Bracklesham Bay, Bognor, and Newhaven.

The Tertiary Beds are represented in Sussex by the following sequence in descending order :

	Thickness.*
Bracklesham Series	500-600 ft.
Lower Bagshot beds	a few ft. only.
London clay	292 ft.
Woolwich and Reading beds	100 ft.

The continuity of the outcrops has been somewhat disturbed locally by subsidiary folding and denudation, a marked anticlinal axis extending westwards from Littlehampton past North Mundham, where another, arranged in echelon slightly to the north, begins, and is continued past Chichester.

Except in a few small pits near Arundel, the Woolwich and Reading Beds are not well exposed in West Sussex. Outliers, however, occur farther to the eastward, and those at Newhaven and Seaford afford good sections.

The Newhaven outlier, resting upon *Actinocamax quadratus*

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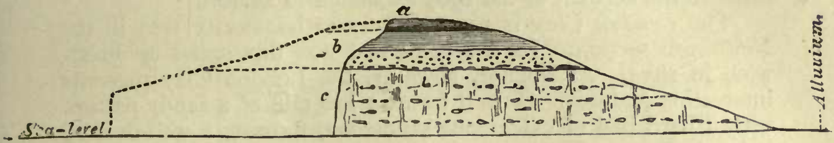
* On the authority of Mr. Clement Reid. See *Memoirs of the Geological Survey*, sheets 317, 332.

Chalk, is well exposed in the cliff section at Castle Hill. This section has been described by Mantell,* Prestwich,† and later by Mr. Whitaker.‡ Details are also given in the reports of the Association excursions in 1887 and 1907.§ As the cliff has receded higher beds have been rendered visible, as is shown in the accompanying diagram by Mr. Whitaker. (Fig. 45.)

FIG. 45.—DIAGRAM SECTION OF THE CLIFF A QUARTER OF A MILE WEST OF NEWHAVEN HARBOUR.—*W. Whitaker.*



a. London Clay.
b. Woolwich and Reading Beds.
c. Chalk.
Gravel omitted.

The dotted lines show the former continuation of the various beds.

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The succession is not easy to see on account of slips, but the following is the general sequence:

POST-TERTIARY.	Coarse, red gravel and sand, about 15 ft.
LONDON CLAY.	Clay, about 10 ft., consisting of brownish clays and loams with a basement bed, about 1 ft. of sandy clay with flint pebbles.
WOOLWICH AND READING BEDS.	Laminated bluish-grey clays, about 5 ft.
	Shell beds, with oyster bed passing into shelly clays, about 6 ft.
	Light-coloured sands and clay, about 6 ft.
	Laminated clays and marl, about 10 ft., with thin shell beds.
	Thin beds of sandy clay with lignite, 6 in.
	Bluish clay and marl, weathering brown, with selenite, 12 ft.
	Sand, 20 ft., yellowish-green or mottled.
	Flint breccia, about 2 ft., with green-coated and iron-stained flints, embedded in green sand and often cemented to a hard projecting band.
	Clay, varying in thickness, not exceeding 1½ ft., containing selenite and Websterite (Aluminite) locally.
CHALK.	Chalk of the *Actinocamax quadratus*-zone.

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* "Geology of the South-East of England," pp. 53-65 (1833).

† *Quart. Journ. Geol. Soc.*, vol. x, p. 83 (1854).

‡ *Quart. Journ. Geol. Soc.*, vol. xxvii, p. 263 (1871).

§ Topley, W., "Excursion to Newhaven," *Proc. Geol. Assoc.*, vol. x (1887), p. 141; Elsden, J. V., *ibid.*, vol. xx (1907), p. 161.

The *Woolwich and Reading Beds* are here very fossiliferous at certain horizons, and yield *Ostrea bellovacina*, *Melania inquinata*, *Cyrena*, *Cerithium*, *Melanopsis*, *Unio*, and *Cypris*, as well as fish teeth, and plant remains. This is the only fossiliferous exposure of these beds in Sussex. The Seaford exposure is less complete, and apparently corresponds with the lower sandy beds only.

Blocks of greywether sandstone occur in places, as at Stanmer Park and at Alfriston. These may be relics of Lower Tertiary Beds. For more complete discussion of these reference is made to the account of the 1907 excursion to Seaford.*

The *London Clay* is not now very satisfactorily seen in the Newhaven section. Its basement bed was first noted by Prestwich in 1854. At Bognor, however, the London Clay presents interesting features. Here it forms a low cliff of a sandy nature, with a hard bed of calcareous sandstone, forming a well-defined ledge known as the Bognor Rocks. Mr. Clement Reid remarks of this rock that it is so conspicuous a feature, running out to sea in an east-south-east direction, that "one is apt to forget that it is a mere subordinate rock-bed, included in a thickness of some 300 ft. of London Clay." The Bognor Rock Bed is very fossiliferous, containing abundant shells, amongst which *Pectunculus brevirostris*, *Pholadomya margaritacea*, *Pinna affinis*, and other species occur. Several of them are figured in the Survey Memoir† by Mr. Clement Reid.

The *Lower Bagshot Beds* are not well exposed, but are believed by Mr. Clement Reid to underlie Pagham Harbour, the excavation of which has, in his opinion, been facilitated by their loose coherence.

The *Bracklesham Beds* occupy the tidal area on each side of Selsey Bill. They can only be examined properly at low water during spring tides.‡ The flat nature of the coast causes the sea at low tide to retreat for a long distance, but the Mixen Rocks, the uppermost visible bed, are only just accessible at lowest tides. These are nearly a mile from the shore. Between the Mixen Rocks and Selsey Bill lie the outcrops of a fine fossiliferous series, dipping in a southerly direction. They were described in 1862 by Rev. O. Fisher.§ Sir J. Prestwich and others have also added to our knowledge of them. Of late years the beds have been studied by Mr. Clement Reid, from whose papers the following details respecting the succession have been summarised.‖ The sequence extends from Chichester Channel south-eastwards towards the Mixen Rocks off Selsey Bill:

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* *Proc. Geol. Assoc.*, vol. xx (1907), pp. 158, 159.

† "The Geology of Bognor," *Mem. Geol. Survey*, sheet 332, p. 3 (1897).

‡ The 6 p.m. low tides are the most favourable

§ *Quart. Journ. Geol. Soc.*, vol. xviii (1862), p. 74.

‖ *Quart. Journ. Geol. Soc.*, vol. xlviii (1892), pp. 344 et seq. Also *Mem. Geol. Surv.*, sheet 332, "The Geology of Bognor," pp. 4-8 (1897).

GENERALISED SUCCESSION OF BEDS ON THE FORESHORE OFF SELSEY.

BRACKLESHAM SERIES.

Clays and sandy rock beds, with *Nummulina variolaria*, *Alveolina sabulosa :* Mixen rocks.
" Cypræa-bed."
" Beloptera-bed " of Dixon : opposite Medmery Farm.
Sands with *Cerithium giganteum :* ¼ mile from Thorney Farm.
Calcareous sands with *Nummulites lævigatus :* Little Park, ½ mile N. of Selsey Coastguard Station.
" Palate bed " of Dixon.
Clays with *Turritella imbricataria :* off Earnley Channel and Park Farm.
Greenish Sands, with large *Cardita planicosta :* S. of Bracklesham Farm.
Clay with small *Cardita planicosta :* due S. of Cakeham Manor House.
Sands with palm fruits (*Nipa*) *:* opposite West Wittering beacon.
Sandy loam with pebble bed : West Wittering, near Harbour entrance.

London Clay and possibly Lower Bagshot Sands : exposed in low cliff above Chichester Channel.

The Mixen Rocks are believed by Mr. Clement Reid to be about 100 ft. below the base of the Barton Clay. The Nummulites Beds, Turritella Beds, and Cardita Beds are also usually well exposed on the east side of Selsey Bill in Pagham Harbour. The above does not represent the full sequence. There are occasional gaps where the evidence is obscured by beach deposits.

At ordinary low water very little of these beds can be seen. This was the condition at the time of our visit in 1904, and the account in our PROCEEDINGS* gives a fair description of the usual appearance of this coast.

THE POST-TERTIARY BEDS.

Throughout the flat coastal plain of West Sussex there are thick coatings of drift which mainly represent three distinct formations. These are (1) marine stratified gravels representing portions of an old sea beach, (2) a more or less unstratified deposit called Coombe rock, (3) terrace gravels representing the older gravels of existing rivers. Sometimes these occur in juxtaposition, and their relative ages can then be determined. At Selsey Bill Mr. Clement Reid was able to make out the following interesting sequence in the pleistocene history of that area. Immediately on the top of the Bracklesham beds is a hard, greenish clay, full of derived Bracklesham fossils and Pleistocene marine mollusca, with, occasionally, large chalk flints and erratic blocks. The latter occupy the base of the deposit, and are often firmly embedded in the surface of the Bracklesham clay. These are the famous Selsey erratics. They consist of various rocks, transported from a distance, and include red and grey porphyritic granite, hornblendic granite, greenstone, schist, slate, quartzite, and sandstone, besides fragments of local origin. Some of the blocks are of large size, weighing several tons. Very similar erratics occur also in Hayling Island. The origin of these erratics is generally ascribed to floating ice. Some of these can generally be seen on the foreshore, protruding through the modern beach, and several were noted on the occasion of our visit in 1904.

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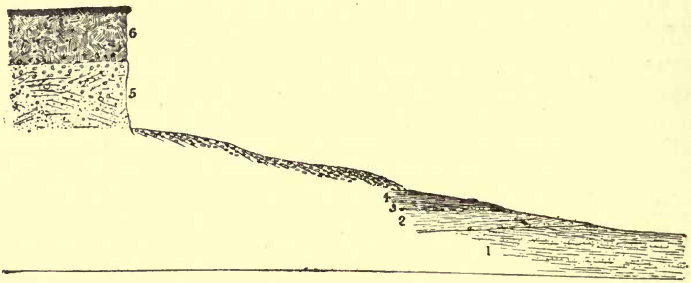
* *Proc. Geol. Assoc.*, vol. xviii, p. 475 (1904).

Succeeding these are occasionally exposed greenish and black muddy deposits with marine shells indicating temperate conditions. Above these is a shingle beach, and covering the whole is a thick deposit of Coombe Rock in the form of a flinty loam, chalky in places. The succession is shown in the accompanying diagram taken from Mr. Clement Reid's paper :*

FIG. 46.—SECTION OF THE CLIFF AND FORESHORE AT SELSEY BILL. —*Clement Reid.*



6. Coombe Rock. 5. Shingle. 4, 3, 2. Marine mud deposits, forming the base of the pleistocene. 1. Bracklesham Beds.

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Very much the same sequence of drift deposits is seen at Brighton, where there is a well-marked raised beach, consisting of waterworn shingle, containing a large variety of foreign rocks in addition to those of local origin, as well as a few fragmentary shells. This beach is covered by a thick bed of Coombe Rock, called by Mantell the "Elephant Bed," on account of the occurrence in it of mammoth, rhinoceros, hippopotamus and other mammals. This deposit underlies a considerable part of East Brighton, extending as far as Kemp Town. Sections have also been exposed at Portslade.

The characters shown in the Selsey and Brighton sections are typical of the Sussex coastal plain. The lower marine beds or raised beach have been found at Ferring, Tortington Common, and in pits about 1½ miles west of Arundel. The material is either shingle or sand, or both combined. The same features are noticed near Slindon Common and Boxgrove. At the latter place foreign rocks, such as quartzite, grit and basalt, occur in the shingle. A good section is exposed in a large sand-pit near Waterbeach, at the south-east corner of Goodwood Park, where 17 ft. of Coombe Rock overlie about 20 ft. of sand with marine shells and flint pebbles. Mr. Clement Reid considers this beach deposit to be of the same age as the lower part of the Selsey sea-beach deposits.

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* *Quart. Journ. Geol. Soc.*, vol. xlviii (1892), p. 355.

There seems to be clear evidence, therefore, that an old sea-beach once covered much of the Sussex coastal plain from Brighton westward. The marine drift occurs up to the height of 130 ft. above sea-level, and its limit seems to be clearly marked by an ancient sea-cliff running past Highdown, near Angmering, to Tortington Common, and then extending for upwards of ten miles along the foot of the Downs north of Chichester. Large spreads of rolled-flint gravel in the entrance to the Findon valley may also mark the site of a former shore-line in this area.

The Coombe Rock.—The name "Coombe Rock" is a purely local term first used geologically by Mantell.* In its typical development it is a rubbly deposit, consisting of unrolled flints and chalk, with faint stratification, occupying the bottoms of many of the dry valleys in the Downs, and spreading out in a wide sheet over the coastal plain. A typical section, 30 ft. thick, is exposed at Birling Gap. It varies considerably in composition, being a coarse, stony gravel or chalky rubble in some places and passing into gravelly loam and brick-earth in other places. This is the deposit described by Prestwich as the Rubble-drift or Head, and is the same as the "Elephant Bed" of Mantell. The relation of this deposit to the marine gravels has already been described. It always occurs above the remains of the raised beach. It occasionally contains mammalian remains, as at Brighton. Remains of mammoth have also been found in this deposit at Worthing, Peppering, near Arundel, Heighton, near Newhaven, and at Eastbourne, which, like Brighton, is built partly upon Coombe Rock. A fine series of mammalian remains has been obtained from Selsey and West Wittering, but there appears to be some doubt whether these are of precisely the same age, as Mr. Clement Reid is inclined to place them with the Estuarine Beds below the raised beach.† A good collection of these remains is in Chichester Museum, where they were inspected on the occasion of the excursion in 1904. In the large pit at Portfield, near Chichester, land-shells have been found in the Coombe Rock.‡

Although the relation of the Coombe Rock to the raised beach is clearly seen, it is not so easy to determine its position with regard to the terrace gravels of the existing river valleys. At Warning Camp, in the Arun Valley, it appears to overlie the true river gravel, but in another section close by the conditions seem to be reversed, and river gravel rests upon 10 ft. of rubbly chalk.

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* "Geology of the South-East of England," p. 31 (1833).

† "The Geology of Bognor," *Mem. Geol. Surv.*, Sheet 332, p. 11 (1897).

‡ Prestwich, J., *Quart. Journ. Geol. Soc.*, vol. xlviii, p. 271 (1892).

The Rubble-drift or Coombe Rock was considered by Prestwich to have been swept down from the chalk hills, spreading out over the coastal plain, and, gradually dropping its load of flints and chalk, becoming gradually finer and more loamy near the coast.* This view was also held by Murchison and Godwin-Austen. These authors considered this deposit on the south of the chalk range as representing a similar spread of flint-drift which occurs on the north of the Downs, occupying the higher contours between Midhurst and Polegate. The main distinction, however, is that whereas on the north of the Downs the angular flint-drift occupies the watersheds,† on the south the rubble drift occupies the valleys and the coastal plain. Mr. Clement Reid has offered the following explanation of the Coombe Rock deposits.‡ He considers they point to Arctic conditions affecting a region not actually submerged, but subjected to violent floods. Owing to the ground being frozen, and the natural drainage disturbed, spring floods rushed down the valley, thawing, tearing up, and carrying away the chalk and spreading sheets of chalk and flint-rubble over the plain in wide confluent deltas. If, therefore, the watershed drifts on the north of the Downs had a similar origin, their present elevated position marks the amount of valley erosion in the Wealden area since the Glacial epoch.

In the river valleys are, here and there, patches of true river gravel forming terraces, and there are wide alluvial plains through which the present rivers flow. Borings in the Arun Valley show that the true valley bottom is now considerably below sea-level, forming, in fact, a kind of fiord, silted up. Chichester Harbour has a similar structure.

Note.—Since writing the above, the author has communicated a paper to the Geological Society adducing evidence to show that the Seaford Tertiary outliers occupy the trough of an east and west uniclinal fold, of which Seaford Head is a remnant. The trough terminates abruptly in the Cuckmere valley, ending apparently in a transverse fault, which may be taken as the eastern limit of the structural area known as the Hampshire basin. This feature, taken in conjunction with the trend of the South Coast, explains the present distribution of Tertiary deposits in this area.§

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* Prestwich, J., *Quart. Journ. Geol. Soc.*, vol. xlviii, p. 271 (1892).
† Elsden, J. V., *Quart. Journ. Geol. Soc.*, vol. xliii, p. 637 (1887).
‡ Reid, C., *Quart. Journ. Geol. Soc.*, vol. xliii, p, 364 (1887).
§ *Quart. Journ. Geol. Soc.*, vol. lxv, p. 442 (1909).

CHAPTER XII.

HAMPSHIRE AND THE BAGSHOT DISTRICT.

By HORACE W. MONCKTON, F.L.S., F.G.S., and H. J. OSBORNE WHITE, F.G.S.

THE COAST SECTIONS.

By H. W. MONCKTON.

THE Association has on three occasions visited the cliffs of Bournemouth and Barton, viz., at Easter, 1880, Easter, 1888, and Easter, 1894, and Mr. Starkie Gardner, who acted as director, or as one of the directors, on these occasions, explained that he did not wholly agree with the classification of strata adopted by the Geological Survey. His views of the relation of the Hampshire Eocene beds to those of the Isle of Wight are very clearly shown by the diagram, Fig. 47, which is reproduced from the *Quarterly Journal of the Geological Society* for 1879 (vol. xxxv, p. 212).

Bed 8 of the diagram, which represents the brightly-coloured sands and sandstone of Studland Bay and the pipe-clay beds of the Wareham-Corfe Castle district of Dorsetshire, is called "Lower Bagshot" by Mr. Gardner, but is termed "Bagshot Beds" on the Geological Survey Map. Bed 7 of Mr. Gardner's diagram, the "Bournemouth Freshwater Series," is also included in the "Bagshot Beds" by the Geological Survey. The cliffs between Poole Harbour and Bournemouth give a grand section in these beds, the details of which are shown in Fig. 48, also by Mr. Gardner, and borrowed from the *Quarterly Journal* (vol. xxxviii, 1882, p. 4). Whatever we are to call these strata there can be no doubt that they are of fluviatile origin, formed in the bed of a large river which flowed in a more or less easterly direction.

Mr. Gardner remarks on these cliffs:* "Their general appearance seaward is that of a confused mass of lenticular patches, now of sand, and now of light- or dark-coloured clay, suggesting forcibly a transverse or oblique section across an old river-valley. The sections up the chines do not present the same lens-shaped patches, but more continuous beds; and it may therefore be assumed that they are somewhat more in the direction of the former channels." The clays in many cases contain beautifully preserved leaves and other vegetable remains, and many good specimens were obtained on the excursions. We may add that a fossil feather was obtained by Mr. Gardner from one of the clay patches.

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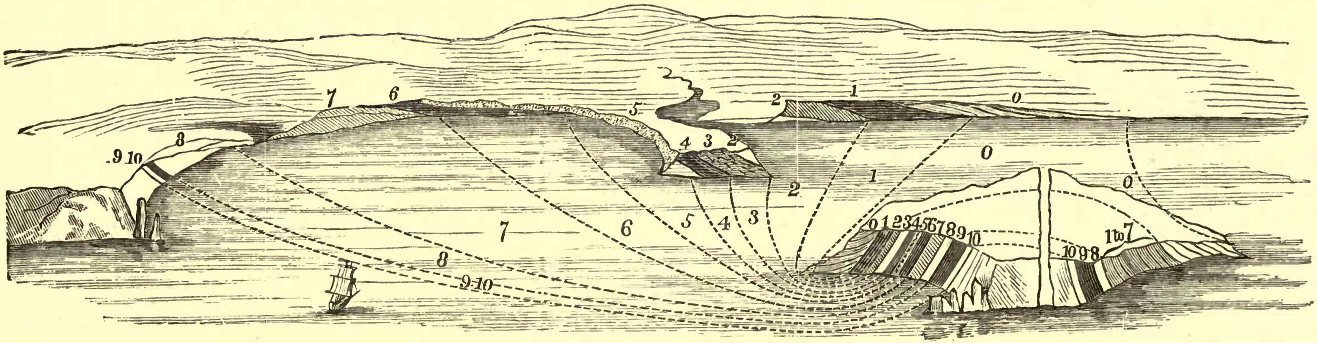
* *Quart. Journ. Geol. Soc.*, vol. xxxviii (1882), p. 5.

FIG. 47.—IDEAL VIEW OF THE ISLE OF WIGHT AND THE ADJACENT LAND.—*J. Starkie Gardner.*

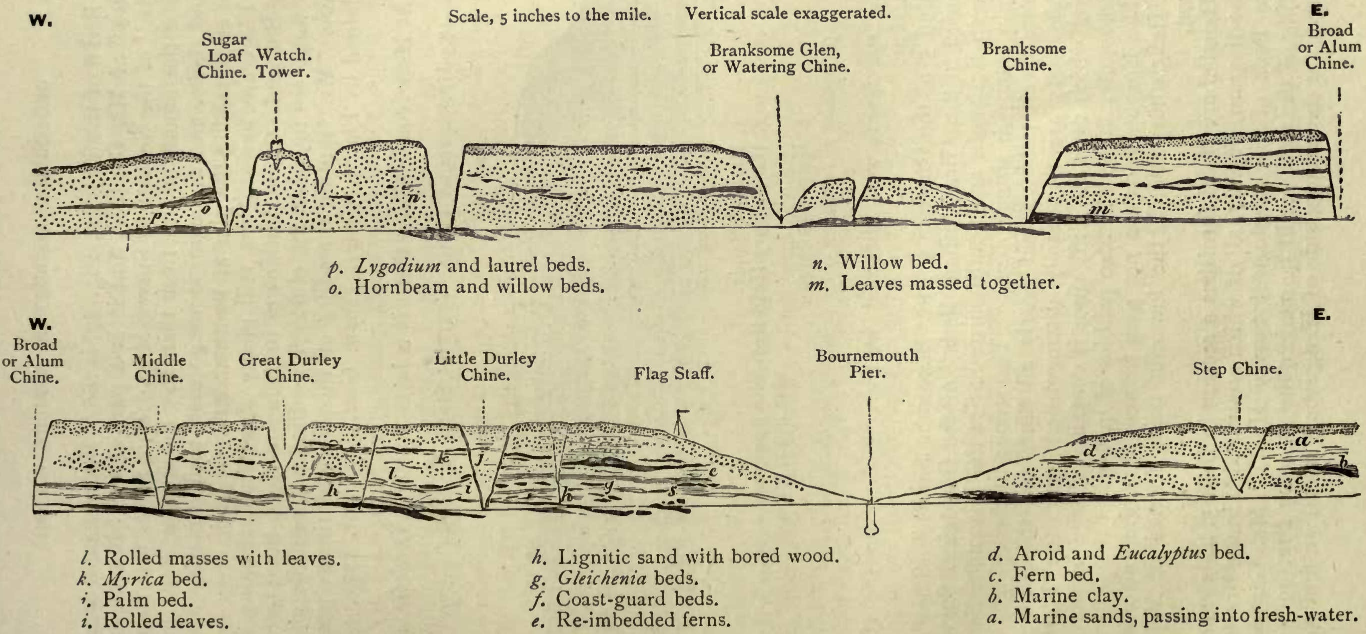
The dotted lines connect the nearly horizontal beds of the mainland with the vertical beds of the island.



0. Oligocene.
1. Barton Beds.
2. Upper Bracklesham and High Cliff white-sand beds.
3. Upper Hengistbury Head Beds with ironstone.
4. Lower Hengistbury Head Beds with green grains.
5. Boscombe Sands.
6. Bournemouth Marine Series.
7. Bournemouth Freshwater Series.
8. Lower Bagshot.
9. London Clay.
10. Woolwich and Reading Beds,

(Reproduced by permission of the Council of the Geological Society.)

FIG. 48.—VIEW OF THE CLIFFS BETWEEN POOLE HARBOUR AND BOSCOMBE, SHOWING POSITION OF PLANT-BEDS, ETC.—*J. Starkie Gardner.*



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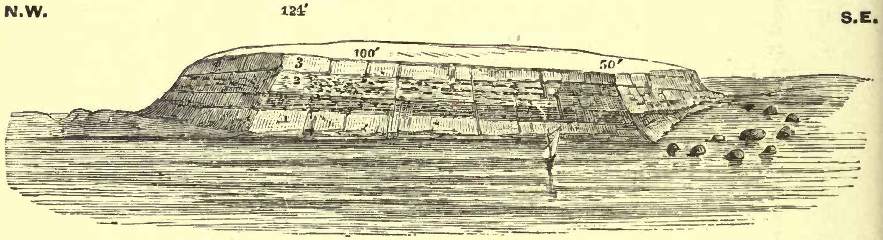
Bed 6 of the diagram, Fig. 47, is the " Bournemouth Marine Series " of Mr. Gardner, and it is a part of the "Bracklesham Beds " of the Geological Survey Map. This Series was formed nearer the mouth of the river than the Freshwater Beds mentioned above, and we begin, as we go east, to find marine fossils soon after passing the pier at Bournemouth.

There are, nevertheless, still plenty of vegetable remains, and near Boscombe Chine portions of branches of trees, three to four feet long, are found in the cliff. The wood has been bored by *Teredo*. Mr. Gardner's reading of this part of the section is explained by Fig. 5, *Quart. Journ. Geol. Soc.*, vol. xxxv, page 225.

At Honeycomb Chine there is a layer full of *Nipadites*, and many specimens were obtained by the members on the 1894 excursion.

FIG. 49.—HENGISTBURY HEAD, WESTERN SIDE.—*J. Starkie Gardner.*



3. Highcliff Sands.
2. Hengistbury Head Beds with ironstone.
" " with green grains.
1. Boscombe Sands.

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Bed 5 of the Diagram is the "Boscombe Sands." They are included in the "Bracklesham Beds" of the Geological Survey. Between Boscombe and Southbourne-on-Sea the Boscombe Sands contain extensive shingle beds. The stones in the shingle are practically all pebbles and nearly all flint, and these Eocene pebble beds are thus easily distinguished from the Plateau Gravel which caps the cliff, since it contains a large proportion of subangular flints, and also pebbles of quartz.

The Eocene Beds are not seen between Southbourne-on-Sea and Hengistbury Head, the low cliff being formed of Valley Gravel.

Hengistbury Head furnishes a section in Beds 5, 4, 3, and 2 of the diagram, Fig. 47, all of which are included in the Bracklesham Beds of the Geological Survey Map. Mr. Gardner's reading of the section will be made quite clear by Fig. 49. On the shore at the western side of Hengistbury Head we find some current-bedded sand with a few layers of pebbles, which are probably a continuation of the sands with shingle of the Boscombe Cliffs, Bed 5 of the Diagram, Fig. 47.

Beds 4 and 3 of Fig. 47 are the Hengistbury Head Beds of Mr. Gardner, and contain some layers of tabular iron concretions and compressed tree stems often of some size. The ironstone was once worked here.

At the top of the Hengistbury Head section we find some sands, which Mr. Gardner believes to be on the horizon of the sands which form Highcliff in Christchurch Bay (No. 2 of Fig. 47).

On the east of Hengistbury Head we cross the mouth of the combined Rivers Stour and Avon, and the rapid changes in the position of the banks of sand and shingle gave rise to discussion on all our excursions to this coast. In Mr. Herries's report of the 1888 excursion he remarks: "The remarkable change in the outlet of the Avon was pointed out. The natural mouth of this river is at Christchurch Harbour, just east of Hengistbury Head, but a bar of shingle having formed across it, the mouth was gradually driven farther and farther eastward, till the river flowing along the shore parallel with the cliff reached the sea under Highcliff House, about two miles off. Then in 1883, during a great storm, this barrier was broken through, and now once more it flows out at Christchurch Harbour. The old course under the cliff is marked by a series of lagoons inside the great shingle bar."*

We now come to the Barton Cliffs, celebrated amongst geologists from early days. The white sand of Highcliff is a prominent feature of the western end of the section. There are two pebble beds in the cliffs, one near the shore and the other near the top of the white sands. About 10 ft. above this latter there is an ironstone band, which is well marked, and can be seen from a distance. About a foot above the ironstone band *Nummulites elegans* occur in a dark-grey clay with grains of green sand. It is stated that on the 1888 excursion this Nummulite band was sought without success, but there is usually no difficulty in finding it if one works upwards from the pebble bed.

This Nummulite band is the best palæontological line of division between the Bracklesham and Barton series, though possibly, from a lithological point of view, it is best to take the pebble bed some 11 ft. lower down as the base of the Barton Series.†

The following section of the Barton Beds at Barton will, we think, be found useful by collectors:

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* *Proc. Geol. Assoc.*, vol. xi, p. xix.

† See Gardner, Keeping and Monckton. *Quart. Journ. Geol. Soc.*, vol. xliv (1888), p. 586, and C. Reid, "Geology of Bournemouth," *Mem. Geol. Survey*, 1898, p. 8.

SECTION OF THE BARTON BEDS—BARTON CLIFF.

The Upper Barton Series.

Thickness, 90 ft. ; *Voluta solandri ; V. scabricula, V. scalaris, V. subambigua, V. humerosa.*

		ft.
i. Long Mead End Beds.	White and tawny sands .	20
ii. Becton Bunny Beds .	(*a*) Clays with a brackish water fauna in the upper part. In the lower part *Oliva branderi* is common	26
	(*b*) Whitish sand without fossils	26
iii. *Chama* Beds . .	Clayey, dark coloured sand .	18

The Middle Barton Series :

Thickness, 53 ft ; *Voluta luctatrix, V. ambigua.*

i. Shell bed, mainly comminuted shells ; when weathered forms hard slabs which lie about the shore. Dark clay, very fossiliferous, with two bands of septaria in the middle. The best fossil zone is a little above the lower Septarian band	20
ii. Clay, more or less sandy, with a band of septaria at the bottom	28
iii. The *Voluta suspensa* bed. Clay, with a band of septaria at the bottom	5

The Highcliff Beds or Lower Barton :

Thickness, 49 ft. ; *Voluta athleta, V. nodosa.* These beds are now almost hidden by the planting, etc., undertaken for the protection of the cliff. The upper part consists of a glauconitic clayey sand, "The Highcliff Sands," about 12 ft. in thickness. The lower part is more clayey. The base of the Barton Series is marked by a band of green sandy clay, full of *Nummulites elegans*, 8 ins. thick.

When the Association last visited these cliffs we found that though the Lower Barton was much hidden, the Middle Barton, or Barton Clay proper, was still open to the collector, and it is recorded that we had luncheon on the "best fossil zone."

The Middle Barton Clays include all the septaria bands that occur in the Barton Series, the lowest of these forming a good landmark for the inferior junction, and the shell bed an unmistakable line of demarcation for the superior limit. This bed sets when exposed to sea water into a hard stone, and is used for building purposes.

The *Chama* beds at the bottom of the Upper Barton are not fossiliferous unless capped by the clays of the overlying Becton Bunny Beds, but when they do contain fossils the *Chama* occurs in great abundance. The *Chama* is rare in the Lower Barton, absent in the Middle Barton, and this is the last appearance of the genus in England.

The Long Mead End Sands contain beautifully preserved, but very delicate, fossils, including *Cerithium pleurotomoides*. These beds have been described as "Upper Bagshot" and as

"Headon Hill Sands," and it has been a matter for discussion whether they should be placed with the Barton or with the Headon. It is, however, probably best to treat them as the top of the Barton Series.*

The Headon Beds are well seen in the cliff section, and a fair number of fossils were obtained on the 1894 excursion. The succession of the strata is as follows:

SECTION OF THE LOWER HEADON BEDS AT HORDWELL.

	ft.	in.
1. Marl, stained with gravel	3	0
2. Limnæan marl (dark layer with serpents' vertebræ, rodents' teeth, etc., 1 in. thick)	0	9
3. Greenish rusty marl, with broken turtle and mammal bones	1	8
4. Laminated sand, with grey partings of clay, darker towards the base, passing down into the *Unio*-beds, with *Unio*, *Paludina*, *Melania turritissima*, in nearly slate-coloured clay. At the bottom there is a layer of seeds	11	0
5. Bright, green marly clay, with crushed *Limnæa*	12	0
6. *Chara*-bed. Lignite and drab clays, with roots, rushes, etc., then lignite, with roots, rushes, and seeds at base	3	9
7. Greenish mottled clay and marl, various kinds, with a black band 4 in. thick near base; *Dreissena*, *Limnæa*, etc.	10	4
8. *Limnæa*-limestone	0	7
Black band	0	1
9. Mottled green marly clay, with masses of clay and iron-stone up to several tons in weight	4	0
10. Crocodile bed (*a*) Very fine pale grey sand, becoming darker at base and more clayey. Layers of *Potamomya plana* at top and bottom. Crocodile-bones with *Cerithium pyrgatum* one-third down	6	4
(*b*) Coprolite bed, with rolled bones and comminuted shells, a thin black layer at bottom	1	0
(*c*) Stiff marly clay, becoming clunchy	4	0
11. Leaf bed. Dark, sandy clay, slightly mottled with yellow, and with roots passing down into drab pipe clay, with black roots and partings	3	2
12. Mammalia bed. Bright green marl, with roots. *Paludina* drifted in pockets. An iron band 8 in. thick, below which there is mottled green marly clay	17	0
13. Impure, friable lignite and clay	2	2
14. Black clay with *Potamomya*, *Dreissena*, *Mytilus* and *Cerithium pyrgatum*	0	7
15. Black clay with roots and occasional broken *Potamomyæ*	0	10
16. Lignite, with fish scales, sand at base, ½ in. thick, with *Cyrena*	0	3

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* See Gardner, Keeping and Monckton, *Op. cit.*, pp. 593-594; and Tawney, *Proc. Cambr. Phil. Soc.*, vol. iv, pt. 3, p. 140.

SOUTH HAMPSHIRE INLAND SECTIONS.—TERTIARY BEDS.

By H. W. MONCKTON.

During the Easter Excursion of 1886 a visit was paid to the cuttings on the railway between Christchurch and Brockenhurst. The beds seen belong to the Barton and Headon series, with overlying gravels. The Barton Clay was very fossiliferous, and included a well-marked band of septaria. The Headon beds were seen to be very much contorted at one place.*

On April 23rd, 1886, a party of our members took a walk round part of the suburbs of Southampton under the guidance of Mr. Whitaker. We give a few extracts from his report: †

"The large pit in Bevois Valley was first visited, and attention drawn to the fine section of Lower Bagshot Sand capped by gravel and showing signs of the passage down into London Clay. Passing on to another pit close to St. Denys Station, the junction of the Bracklesham beds with the Lower Bagshot Sand was seen, the former series consisting of clayey loam, in the bottom part of which flint pebbles occur. Attention was drawn to the fact that in the neighbouring low ground of St. Denys excavations for sewers had proved the occurrence, beneath the gravel, of London Clay with highly-fossiliferous septaria.

"The formations below the Bracklesham beds . . . . have been brought up by a rise of the beds, which is a continuation of the great saddle-back bringing up the Chalk of the Portsdown ridge many miles eastward.

"From St. Denys the course was through Portswood, when a brickyard, apparently in the loamy passage beds from the Lower Bagshot to the London Clay, was seen; and then the Church Farm sandpit, Highfield, a little higher up the same slope, was examined. Here the Lower Bagshot Sand was again seen capped by a gravelly and loamy deposit, the lower part of which clearly consisted of the broken-up, pebbly base of the Bracklesham beds, from which it would be inferred that the latter must come on directly above. This inference was shown to be justified by the sections at the neighbouring Highfield brickyard at a rather higher level, close to the eastern edge of Southampton Common, when the junction of the Bracklesham beds and the Lower Bagshot beds was again seen at a much higher level than at St. Denys."

On April 8th, 1887, Mr. Whitaker conducted a party of the Association to the Southampton Waterworks near Otterbourne, between Southampton and Winchester. ‡ He remarked "that the excavation for the reservoir had shown a most interesting and unique section, the Bagshot Pebble-beds resting somewhat irregularly on the sandy top London Clay in the absence of the Lower Bagshot Sand."

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* See *Proc. Geol. Assoc.*, vol. ix, p. 524, and *Quart. Journ. Geol. Soc.*, vol. xliv (1888), pp. 597-599.

† *Proc. Geol. Assoc.*, vol. ix, p. 522.

‡ *Proc. Geol. Assoc.*, vol. x, p. 133. See also C. Reid, "Geology of Southampton," *Mem. Geol. Survey*, 1902, p. 14.

On April 9th the members examined sections on the railway then in course of construction between Netley and Fareham.

We quote Mr. Whitaker's account of a cutting between the Titchfield Valley and Fareham :*

"The cutting will be a long one, but its western part was almost all that was to be seen. This, however, was of considerable interest, for the more or less sandy London Clay contained many, though mostly very fragile, fossils; the discoloration of the upper part, from dark grey to brown, by peroxidation of the ferruginous colouring-matter, was plainly seen, and Londoners were probably much astonished at the occurrence of two continuous pebble-beds, each about a foot thick, in the midst of their own particular clay, no such occurrence having been noted in the London Basin.† These beds consisted of flint pebbles with fossils (chiefly oyster-shells) in a loamy matrix; they were about 2 ft. apart, and in one of them Mr. E. Westlake found a specimen of a large *Terebratula,* the first of its sort in the formation. This turned out to be *Terebratula bisinuata*, a species that has very rarely been found in Barton and Bracklesham beds, though plentiful sometimes in the Calcaire grossier of France. Since the excursion a great number of specimens have been found by Messrs. Westlake, W. Dale, J. W. Elwes, Shore, and Whitaker. They seem to occur in nests like miniature mussel-banks."

THE CHALK.

By H. J. OSBORNE WHITE.

In the Hampshire mainland this formation appears to have a maximum thickness of 1,000 to 1,100 ft., of which about 200 ft. may be assigned to the Lower division, 180 ft. to the Middle, and 700 ft. to the Upper; but these figures are merely rough estimates.

The Lower, or Cenomanian, Chalk comprises:

		ft.
2. ZONE OF *Holaster subglobosus*.	Sub-zone of *Actinocamax plenus*. Grey laminated marl containing a thin bed of white or greyish chalk. *Act. plenus*, etc. (10 ft.). Firm, massive, greyish-white chalk, with *Hol. subglobosus*, *Hol. trecensis*, *Cidaris bowerbanki*, etc. . . .	100 ?
1. ZONE OF *Ammonites* [*Schloenbachia*] *varians*.	Chalk Marl; grey marly chalk, with *Schloenbachia varians*, etc. Chloritic Marl; glauconitic and phosphatic marl, with *Aucellina gryphæoides*, etc. (1½ to 4 ft.) . .	100 ?

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* *Proc. Geol. Assoc.*, vol. x, p. 138.

† Thin pebble-beds occur in the London Clay at Aldershot. See *post*, p. 289.

Beds belonging to this division are exposed in the neighbourhood of Alton, at the western end of the Weald area; also in the railway cuttings south of Burghclere, in the anticlinal inlier of Kingsclere, and in pits in the similar inlier of Winchester. The Burghclere section, which shows portions of both zones, and probably the Winchester sections (at Bar End and Chilcombe), which at present show little chalk below the *Act. plenus* marl, were visited by the Association in the Easter of 1888, but no details are given in the report of the excursion.*

The Middle Chalk (Turonian), which is exposed in the same parts of the country as the Lower Chalk, consists of:

			ft.
2.	Zone of *Terebratulina.*	White and greyish-white chalk, with seams of grey marl, and a few flints *Terebratulina gracilis*, var. *lata Inoceramus brongniarti*, etc.	100 ?
1.	Zone of *Rhynchonella cuvieri.*	Hard, white and greyish-white nodular chalk; flints rare and small. Melbourn Rock at base . . . *Inoceramus mytiloides* (= *I. labiatus*), *Rhyn. cuvieri*, etc.	80 ?

The Melbourn Rock was seen at Burghclere in 1888, and in a pit to the south of Alton during the Selborne excursion in 1891;† while the *Terebratulina*-beds were inspected at Star Grove, near East Woodhay,‡ in 1902, and probably also in the large quarry in St. Giles's Hill, Winchester, in 1888.

The Upper Chalk (Senonian) occurs at the surface over the greater part of central and northern Hampshire, and has been quarried, for marling the land and other purposes, in many hundreds of pits, which are now, for the most part, disused and overgrown.

This division includes the following zones:

			ft.
6.	Zone of *Belemnitella mucronata.*	Soft white chalk, with few flints . . . *Bel. mucronata*, *Magas pumilus*, etc.	100 ?
5.	Zone of *Actinocamax quadratus.*	Soft, white chalk, with flints—many being small and sub-spherical . . . . . *Act. quadratus*, *Ostrea lateralis* var. *striata*, *Offaster pillula*, *Echinocorys scutatus* (gibbous form), etc.	200 ?
4.	Zone of *Marsupites testudinarius.*	Soft, white chalk, with few flints. . . . . Sub-zone or band of *Marsupites.* Sub-zone or band of *Uintacrinus.* *Echinocorys scutatus* (pyramidate), etc.	100 ?
3.	Zone of *Micraster cor-anguinum.*	White chalk, with many flints. . . . . *Micraster cor-anguinum*, *Conulus albogalerus*, *Cidaris perornata*, etc.	200 ?
2.	Zone of *Micraster cor-testudinarium.*	White chalk (nodular in part), with many flints . . . . *Micraster præcursor*, *Inoceramus lamarcki*, etc.	50 ?

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* *Proc. Geol. Assoc.*, vol. xi (1889), pp. xv, xvi.

† *Ibid.*, vol. xii (1891), p. 192.

‡ *Ibid.*, vol. xvii (1902), p. 394.

1. ZONE OF *Holaster planus.*	Greyish-white nodular chalk, with flints. Sub-zone of *Heteroceras reussianum* (marked in places by Chalk Rock) at or near the base *Hol. planus*, *Micraster leskei*, *M. præcursor*, *Heteroceras reussianum*, *Scaphites geinitzi*, *Solariella gemmata*, etc.	50 ?

Railway cuttings, showing an almost complete sequence of the beds between the base of the *H. planus*-zone and the top of the zone of *Marsupites*, were examined, by an Association party, between Highclere and Whitchurch Stations, during the excursion of 1888, before mentioned. The occurrence there of the Chalk Rock, with the usual green nodules and "some fine gasteropods," and the pronounced dips to north and south, due to the Kingsclere anticline, are noticed in the report, by Mr. R. S. Herries.

During the Easter excursion of 1887, the Association examined a pit in the *Act. quadratus*-zone at or near Shawford, south of Winchester. It is recorded* that the chalk there exposed afforded "an abundant supply of *Holaster* [*Offaster*] *pillula.*"

The *Bel. mucronata*-chalk is believed to be confined to the southern part of the county. No sections have been seen by the Association.

THE TERTIARY AND POST-TERTIARY BEDS OF NORTH HAMPSHIRE AND OF THE BAGSHOT DISTRICT.

By H. W. MONCKTON.

The succession of the strata above the Chalk in this part of the country is very well shown by the section through Aldershot (Fig. 50) which Capt. Lyons has kindly allowed us to reproduce.† It will be seen that we have, upon the Chalk, a representative of the Woolwich and Reading Series, that we then get a thick bed of London Clay, and that above it the various beds, classed as Bagshot, complete the solid geology, and are only overlain by patches of Drift.

The Woolwich and Reading Beds.—I have not been able to find any representative of the estuarine beds forming the Woolwich phase of this formation in the area now under consideration. There is, however, a layer with *Cerithium* and *Cyrena* at the top of the Series in the brickfield, close to Guildford Station, to the south-east of the district, and *Cerithium*, together with various marine shells, have been found at Reading to the north-west, in that case near the bottom of the series.‡

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* *Proc. Geol. Assoc.*, vol. x (1887), pp. 132, 133.
† *Quart. Journ. Geol. Soc.*, vol. xliii (1887), p. 431, Fig 1.
‡ *Ante*, p. 226.

The bed of *Ostrea* which usually occurs at the bottom of the Series has been recorded from near Farnham.*

The thickness of the Series in this district is about 60 ft., and the beds consist of mottled clay with some sand.

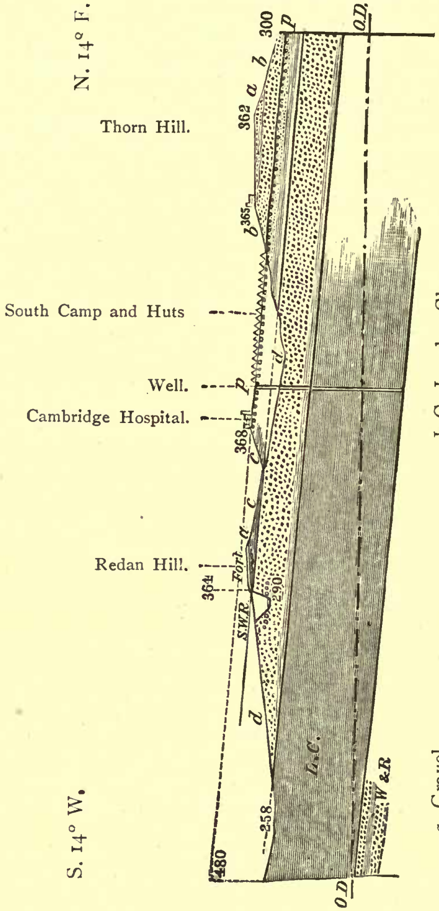

FIG. 50.—SECTION FROM THORN HILL TO REDAN HILL, ALDERSHOT.—*H. G. Lyons.*

a. Gravel.
b. Upper Bagshot.
c. Middle Bagshot.
d. Lower Bagshot.

L.C. London Clay.
W. & R. Woolwich and Reading Beds (position inferred).
P. Pebble-bed.

Scale: Horizontal, 4 in. to 1 *mile. Vertical,* 8 *in. to* 1 *mile. Dip* 2½° *North. Heights in ft. above O.D*

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The London Clay.—This formation is here a bed of clay some 340 ft. in thickness. Prestwich obtained a number of fossils from it in the railway-cutting near Newnham, between Hook and Basingstoke.†

There is a brickfield to the south of the railway near this cutting, and the writer found in it a layer of *Cyprina scutellaria* with valves closed and united. There are usually fair sections in London Clay in the brickfields near Aldershot Station. The clay contains a few bands of pebbles, and the writer saw a section at Hang Wood, Nately Scures, where the surface was formed of a mass of pebbles six inches in depth, resting upon London Clay. Another, and probably similar, patch is marked on the Geological Map at Binfield's Farm, north-west of Basingstoke, and these pebbles were probably derived from the thin pebble-beds, which occur in the London Clay of this district.* Fossils are fairly common in the upper part of the London Clay at Wokingham and Bracknell, and they usually appear to have lived where we find them, and suggest a fairly deep water deposit, thus differing from the shore-like accumulations of shells in the Basement Bed of the London Clay, which is exposed in a brickfield near Nately Scures.

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* See Prestwich, *Quart. Journ. Geol. Soc.*, vol. x (1854), p. 97.
† *Quart. Journ. Geol. Soc.*, vol. iii (1847), p. 371.

The Lower Bagshot Beds.—The London Clay becomes more or less sandy at the top, and passes up into a series of sands, with subordinate beds of clay, named the Bagshot Sands, by Warburton, in 1821.† The main mass of this formation extends from Hampshire into the adjoining parts of Berkshire and Surrey, and the whole area will be dealt with in this chapter.

The Lower Bagshot Beds have already been mentioned at page 229. Their character is very uniform, and there are many sections in the Bagshot district. Pebble-beds occur, but are not so common as in West Berkshire, and locally, beds of clay are found. One of these clay-beds, at Walton Common, has been described by W. H. Hudleston,‡ and a good deal of clay was found in the Lower Bagshot Beds in a well at D. Lines, Aldershot.§

Vegetable remains are occasionally found, and casts of marine shells occur in considerable abundance in a bed of sand some 3 ft. thick in a pit near Jackman's Nursery Garden, about a mile south-west of Woking Station.‖ This is close to the top of the formation.

The Bracklesham Beds.—These are the "Middle Bagshot" and "Middle Bagshot Sands" of the sections Figs. 50, 51. They are essentially a clayey series, interposed between the sands of the Lower Bagshot Beds and those of the Upper Bagshot Beds. Beds of pebbles occasionally are found, and there is nearly always a good deal of, more or less, clayey green sand. The green sand indeed is so marked a feature that Prestwich in one place speaks of the series as the "green-sand division."

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* See Well Section at Aldershot, H. G. Lyons, *Quart. Journ. Geol. Soc.*, vol. xliii (1887), p. 434.

† *Trans. Geol. Soc.*, 2nd Series, vol. i, pt. i, p. 48.

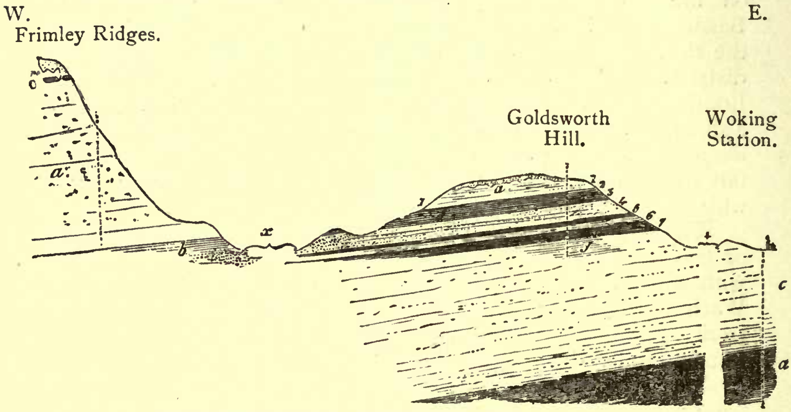
‡ *Quart. Journ. Geol. Soc.*, vol. xlii (1886), p. 147.

§ H. G. Lyons, *Quart. Journ. Geol. Soc.*, vol. xliii (1887), p. 434.

‖ *Proc. Geol. Assoc.*, vol. xv, p. 187.

Fossils are not common, but sufficient have been found to prove that these beds belong to the marine Bracklesham Series. Teeth and bones of fishes are recorded by Prestwich from Goldsworth Hill, near Woking, and from Shapley Heath, near Winchfield.* At both localities there are deep cuttings on the London and South-Western Railway, and a collection of fish-teeth, etc., was made from the Shapley Heath and Goldsworth cuttings on our excursions of July 21st, 1900, and September 21st, 1901.†

FIG. 51.—SECTION FROM FRIMLEY RIDGES TO WOKING STATION.
—*Prestwich.*



The following is abridged from *Quart. Journ. Geol. Soc.*, vol. iii (1847), p. 382.

	Feet.
a. Upper Bagshot Sands	150
b. Middle Bagshot Sands :	
1. Greenish sand, with a few pebbles	2
2. Sandy clays	11
3. Grey clay, with traces of lignite	1
4. Green sand, with fossils	16
5. Compact lignite	1
6. Sandy clay, the upper part with green sand tubes	6
7. Brown compact clay, with sand and traces of vegetable remains	8
c. Lower Bagshot Sands	130
d. London Clay	—

x. Interval of 3 miles.
y. Dark grey clay in the Lower Bagshot Sands.
† Interval of ¼ mile. In both these spaces the strata are continuous.
.... Strata proved.

(Reprinted by permission of the Council of the Geological Society.)

Still more recently Mr. Coomaraswamy has collected from a third locality in the same part of the series near Brookwood, and has published a list of the fish-teeth from the Bagshot Sands (London Basin).[*]

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* *Quart. Journ. Geol. Soc.*, vol. iii (1847), p. 390.
† *Proc. Geol. Assoc.*, vol. xvi, p. 521, and vol. xvii, p. 265.

Casts of shells have been recorded from the Bracklesham Beds of the Bagshot district, and in one case well-preserved shells were obtained. They were from a well at Yately-Green, described by Dr. A. Irving, who exhibited some specimens at the Geological Society.[†] Prestwich gives a list of shells from this series at Goldsworth and Shapley, and also from the heaths of Chobham Place and Winchfield,[‡] and Mr. W. H. Herries published a list from the Ascot-Bagshot Railway.[§]

The Upper Bagshot Beds.—These are the "Upper Bagshot Sands" of Prestwich and, like the Lower Bagshot Beds, are practically a series of light-coloured sands. There is even less clay in the Upper than in the Lower Bagshot Beds; the thin layers of pipe-clay so common in the latter formation being absent, and there is no record of thicker clay-beds, though the sand is rather loamy in places. The Lower Bagshot Beds are as a rule current-bedded, but in the Upper Bagshot Beds current-bedding is very rare, and indeed the only sign of bedding at all usual is a banding of variously-tinted yellow and white sands. There is a well-marked and persistent pebble-bed at the bottom of the series.

The only fossils from the Upper Bagshot Beds known up to now are casts of marine shells, but they are sufficient to enable us to say with tolerable certainty that the Upper Bagshot Beds of the Bagshot district are on the horizon of the Lower Barton Beds of the Hampshire coast.[‖]

The greatest known thickness of the Upper Bagshot Beds is 228½ ft. at the well at the Albert Asylum on Chobham Ridges, and as there are no overlying beds but Drift in the district the full original thickness cannot be known.

The Sarsen Stones.—Prestwich mentions the "well-known blocks of light-coloured or nearly white saccharine sandstone," and remarks that they are "met with chiefly in the upper beds of these [Upper Bagshot] sands generally just below the gravel."[¶] These blocks are very common on the hills and plateaux of the district, and are more especially abundant on one of the highest of these plateaux, Chobham Ridges, but, though I have watched the sections for a good many years, I have never seen one of these blocks which had the appearance of being *in sitû*; they all seemed to have been more or less water-

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[*] *Proc. Geol. Assoc.*, vol. xviii, p. 83.

[†] *Quart. Journ. Geol. Soc.*, vol. xli (1885), p. 500.

[‡] *Quart. Journ. Geol. Soc.*, vol. iii (1847), p. 390.

[§] *Geol. Mag.*, dec. 2, vol. viii (1881), p. 171; and see also, *Quart. Journ. Geol. Soc.* vol. xxxix (1883), p. 349; and H. W. Monckton, "Short Papers," Edin. 1893, p. 29.

[‖] See Gardner, Keeping, and Monckton, Upper Eocene (Barton and Upper Bagshot Formations), *Quart. Journ. Geol. Soc.*, vol. xliv (1888), p. 578.

[¶] *Quart. Journ. Geol. Soc.*, vol. iii (1847), p. 384.

or weather-worn. Their position shows that they are newer than the highest Bagshot Beds still left in the district and older than the oldest Drift. I have suggested that in the Chobham Ridges case at all events they are relics of an old land-surface formed of Upper Bagshot Sand.[*]

The Drift.—There are in this district many, and in some cases, large sheets of gravel, both on the hills, or plateaux, and in the valleys. At one time it was generally supposed that the gravels of the higher plateaux were of marine or estuarine origin, whilst those of the valleys were formed after the retreat of the sea.[†] An examination of these deposits has, however, led me to believe that they are all river-gravels, or in any case of subaërial origin.[‡]

One interesting feature about many of the gravels is that they contain fragments and pebbles which have clearly been derived from the Hythe Beds of the Lower Greensand, but the rivers of the district do not now drain any part of the Hythe-Bed area, and, in short, it is pretty clear that a river, corresponding more or less to the Blackwater, drained at one time a great area now in the basin of the River Wey.[§] These Hythe Bed fragments are very rare in the highest gravel of the district—that of Cæsar's Camp and Upper Hale, Aldershot; they are abundant in the sheet of gravel on Chobham Ridges, which is at a rather lower level, and even more abundant in the patches of gravel near Ascot at a level of a little above 300 ft. O.D. The Hythe-Bed fragments are found in the gravels of Hazeley Heath, Heckfield Heath, and Spencerwood Common, but not in those of the hills farther to the west, showing that the gravel of those hills belongs to a different river with a drainage-area which did not include the Hythe Beds.

Some stones which Mr. Shrubsole believed to be Eolithic Implements were found in the gravel of Finchampstead Ridges at a level of a little over 300 ft. O.D.,[||] and implements have been recorded from near Camberley.[¶]

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[*] *Rep. Brit. Assoc.*, Southport, 1903, p. 669.

[†] See Col. Cooper King. History of Berkshire. Elliot Stock (1887), pp. 1-9.

[‡] See H. W. Monckton. *Quart. Journ. Geol. Soc.*, vol. xlviii (1892). p. 29, and vol. liv (1898), p. 184.

[§] See H. Bury, *Quart. Journ. Geol. Soc.*, vol. lxiv, p. 318.

[||] *Report Wellington College Nat. Sci. Soc.*, for 1901, p. 58 and Plate.

[¶] *Proc. Geol. Assoc.*, vol. vi, 329; *Record of Excursions*, p. 286.

CHAPTER XIII.

WILTSHIRE.

By HORACE B. WOODWARD, F.R.S., F.G.S.

WILTSHIRE is a county full of interest to the geologist, rich in association with some of the early workers and in localities which they have made famous in the history of the science. Sedgwick remarked in 1831, in his well-known appreciation of William Smith, that "it was by tracking his footsteps, with his maps in my hand, through Wiltshire and the neighbouring counties, where he had trodden nearly thirty years before, that I first learnt the subdivisions of our oolitic series."* The journey of Sedgwick was made in July, 1820, when he examined "all the strata from the foot of the Wiltshire chalk-downs to their termination in the ravines near Bath." Excepting only the Eocene, he then saw something probably of all the formations with which we have to deal.

The county records take us as far down as the Lias, but no farther. So straightforward, however, is the geological structure that there are no great controversies about the age and relationship of any of the formations. No eruptive rocks disturb or modify them, and no accumulations of glacial drift conceal any of the outcrops of Jurassic, Cretaceous, and Tertiary formations. Nevertheless, the area has not been unruffled by the "ups and downs" of these geological ages, and there are noteworthy breaks in the succession of deposits, accompanied by evidence of extensive erosion at different periods.

Nothing is known of the nature of the Palæozoic floor, nor even of any New Red rocks beneath the covering of newer strata. Perhaps the deepest sinking was that at Swindon, which was carried to a depth of 736 ft., touched the base of the Forest Marble, and encountered a copious supply of tepid water almost as saline as sea-water. The suggestion made by the writer in 1886, after the completion of the shaft, was that "the saline waters issue from Palæozoic strata, against a ridge of which the Lower Secondary strata abut," and that "this underground ridge may be some miles to the south of Swindon."†

North Wiltshire is especially noted for saline waters, as at Melksham, Holt, Purton, and other localities; so much so, in fact, as to cause anxiety to those who seek supplies of drinking water.

As before mentioned, the record of Wiltshire geology com-

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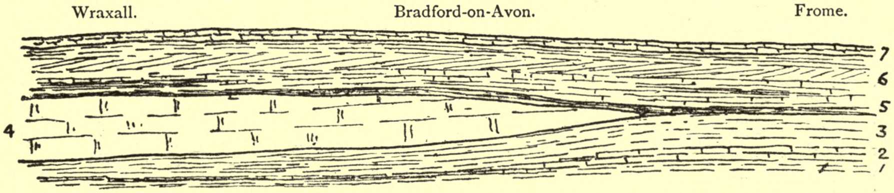
* *Proc. Geol. Soc.*, vol. i, p. 278. See also "Life and Letters of the Reverend Adam Sedgwick," vol. i, p. 217.

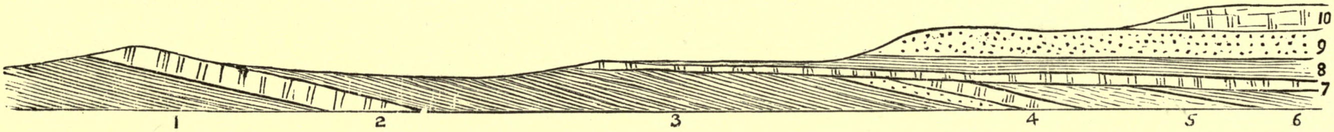
† *Quart. Journ. Geol. Soc.*, vol. xlii, p. 307.

FIG. 52.—DIAGRAM-SECTION FROM NEAR BATH TO FROME.—*H. B. Woodward.*



7. Cornbrash.
6. Forest Marble.
5. Bradford Clay.
4. Great Oolite.
3. Upper Fuller's Earth Clay.
2. Fuller's Earth Rock.
1. Lower Fuller's Earth Clay.

FIG. 53.—DIAGRAM-SECTION TO SHOW THE RELATIONS OF THE OOLITIC AND CRETACEOUS STRATA IN WILTSHIRE.



10. Chalk.
9. Upper Greensand.
8. Gault.
7. Lower Greensand.
6. Wealden Beds.
5. Purbeck Beds.
4. Portland Beds.
3. Kimeridge Clay.
2. Corallian Beds.
1. Oxford Clay.

(*Figs.* 52 *and* 53 *are reprinted by permission from H. B. Woodward's "Geology of England and Wales."*)

mences with the *Lias*, which is exposed in the deep, ramifying valleys of the Box brook and along the course of the more potent Lower Avon, where it traverses the county north of Limpley Stoke. The subdivisions of the Lias in this region have yet to be defined in detail on our Geological Survey maps; our knowledge indeed is limited, as but few sections have been opened in these strata. The Marlstone is meagrely represented as a rock-bed, and the mass of the Lias above and below it, until we reach the Lower or Blue Lias stone-beds, consists in the main of blue clays. To add to the difficulties, there is much evidence of down-wash and land-slipping on the steep grassy slopes of the valleys. Above the Lias come the *Midford Sands* and *Inferior Oolite*, seen in the valley of the Lower Avon near Limpley Stoke, but the sequence is not fully represented, as the Midford Sands are covered by the upper beds of the Inferior Oolite belonging to the zone of the Ammonite *Parkinsonia Parkinsoni*.* These beds, however, can be best studied in the bordering county of Somerset.

In the course of our excursions we have seen something of the next great group of rocks, the Great Oolite series, comprising the Fuller's Earth or Fullonian, the Great or Bath Oolite, the Forest Marble and Bradford Clay,† and the Cornbrash. Malmesbury, Yatton Keynell, Chippenham, Corsham, and Bradford-on-Avon are among the famous localities. We have seen the exposures on the South Wales Direct Railway near Hullavington in 1901; and we have traversed the succession on many occasions in passing from Chippenham through the Box tunnel to Bath. (See Fig. 52.)

The economic *Fuller's Earth*, which is from 4 to 7 ft. thick, has been worked mainly at Midford, in Somerset, near Tucking Mill, once the residence of William Smith, which was visited by the Association in 1893. The material obtained near the borders of Wiltshire was utilised in the cloth mills at Bradford-on-Avon, Trowbridge, and Calne, its peculiar detergent properties having been found useful in cleansing woollen cloths, for which purpose it was much more extensively used than it is now.‡

Analyses of the Fuller's Earth by Mr. J. Hort Player show that its properties are not due to chemical composition, but to physical constitution, the earth not being plastic like ordinary clay, but falling to a powder under water.§ Further research on the nature and origin of economic Fuller's Earth is to be desired.

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* See L. Richardson, *Quart. Journ. Geol. Soc.*, vol. lxiii, p. 406. The upper beds of the Inferior Oolite are sometimes, but I think inappropriately, grouped with the Bathonian. They belong to the Bajocian of d'Orbigny.

† The foregoing comprise the true Bathonian of d'Orbigny.

‡ As early as the reign of Edward III, cloth-making appears to have been an important industry in Wiltshire. A. E. W. Marsh, "History of the Borough and Town of Calne," p. 118. A good deal of Fuller's Earth was brought from Woburn in Bedfordshire.

§ *Proc. Geol. Assoc.*, vol. xiii, p. 127.

The *Great Oolite* forms the main features in north-western Wiltshire, portions of the dip slope of the Cotteswold Hills, with fine scarps along the upper part of the Box Valley, as at Castle Combe, once the residence of G. Poulett Scrope. This region was visited in 1896, when we journeyed onwards to Malmesbury. The Great Oolite is extensively quarried, or rather mined, at Corsham and Box, the underground ways being estimated to extend, in combined length, to more than 30 miles. Full particulars of the workings were given to us by the Rev. H. H. Winwood and Mr. George Hancock.* Again at Bradford-on-Avon there are other extensive underground workings.

To the south and south-west this formation disappears; it wedges out, and is not replaced by strata of Fuller's Earth or of Forest Marble. The last exposures of Great Oolite are seen in the valley about three miles south-west of Freshford, near Norton St. Philip, in Somerset, and beneath them there is evidence of Fuller's Earth with its band of Fuller's Earth Rock.

At Murhill, near Winsley, and again at Ancliff or Avoncliff, our attention was drawn to the fossiliferous rag-beds above the Great Oolite freestone. In a weathered face of rock, at the former locality, the indefatigable Mr. W. H. Wickes obtained fine examples of the Coral *Calamophyllia*, numerous specimens of Polyzoa, and minute Gasteropods, the last-named belonging to forms described by Sowerby from fossils collected by Lonsdale. In reference to these species W. H. Hudleston remarked that "it was to be regretted that such small forms had been taken as types, because some of them, at any rate, might be regarded as immature organisms."†

Above the Great Oolite at Bradford-on-Avon is the celebrated *Bradford Clay*, and that deposit, which is the basement-bed of the Forest Marble, extends southwards into Dorsetshire, where it rests directly on the Fuller's Earth formation, without, as before noted, the intervention of the Great Oolite.

It is a case of unconformable overlap, or "overstep," as J. G. Goodchild called this type of unconformity. The Forest Marble is notably a shallow-water formation, and may, in part, locally, at any rate, be derived from the destruction of the Great Oolite. Indeed, "the structure of the oolitic beds, the grains being irregularly mingled with comminuted shells, and lignite, or scattered in a sandy, as well as in a calcareous matrix, suggest the notion that they may have been thus derived,"‡ and this view was put forward in 1879 by H. C. Sorby.§

In many parts of North Wiltshire we find it hard to draw a line, a geological boundary-line, between Forest Marble and Great Oolite; there the Bradford Clay is not persistent as a lithological division. One of its characteristic fossils, the *Terebratula coarctata*, is found also in the upper beds of the Great Oolite.*

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* *Proc. Geol. Assoc.*, vol. xiv, p. 348.

† *Proc. Geol. Assoc.*, vol. xiii, p. 134.

‡ *Mem. Geol. Survey.* "Jurassic Rocks of Britain," vol. iv, p. 259.

§ "Presidential Address," *Quart. Journ. Geol. Soc.*, vol. xxxv, *Proc.*, p. 83.

The Bradford Clay at Bradford is for the most part an unfossiliferous clay some 10 ft. thick; but at its base is a rich fossil bed 1 or 2 ft. thick that rests directly on the Great Oolite. The surface of that formation was locally the home of the Bradford, or Pear Encrinite, *Apiocrinus parkinsoni*, of which remarkably fine specimens were obtained in old times. Some of us saw in 1885 the rich collection of Dr. J. Chaning Pearce, formed many years previously by his father. Under the guidance of the Rev. H. H. Winwood, we visited some of the sections in 1893.†

The *Forest Marble* is well developed in the country between Malmesbury and Bradford-on-Avon, and it presents diverse phases of sedimentation. Largely a clay formation when regarded from an agricultural point of view, it yet comprises amid a mass of shales important beds of false-bedded oolitic limestone; thin films of calc grit with curious track-like markings that were described and figured by Scrope; fissile limestones that are still shaped as of old for roofing purposes at Atworth;‡ sands and sandstones concreted into doggers with pot-lid surfaces, as near Malmesbury, on the Somerset borders at Charterhouse Hinton, and at Norris Hill, south-west of North Bradley, in Wiltshire.

The *Cornbrash* where exposed in shallow quarries presents the familiar rubbly limestone, with the characteristic *Avicula echinata*, poorly preserved lamellibranchs, such as *Gresslya* and *Homomya*, the Ammonite *Macrocephalites macrocephalus*, many brachiopods, notably *Waldheimia obovata*, and usually at the base *Terebratula intermedia.* We have examined sections near Chippenham and at Hullavington.

The *Oxford Clay* occupies a large area in North Wilts, formerly a wooded tract embracing Braydon Forest, and famous in the annals of geology for the *Kellaway's Rock*, or "Kelloway's Stone," described by William Smith, which, in the old days of parish road-mending, supplied material over a large tract of clay-country.

In 1896 we visited the exposures on the banks of the Avon about half a mile below Kellaway's Bridge§—a truly classic locality as the fossils had attracted the attention of Lhwyd in 1699. The higher beds of the Oxford Clay were extensively excavated during the construction of the Great Western Railway, in the neighbourhood of Christian Malford, for material to be used in embankments. Then large numbers of fossils were collected by William Buy, a carpenter and joiner, of Sutton Benger, to whom we are indebted for the majority of the specimens from that famous locality.

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* *Proc. Geol. Assoc.*, vol. xiv, p. 343, vol. xvii, p. 147.

† *Proc. Geol. Assoc.*, vol. xiii, p. 133. See also *Mem. Geol. Survey*, "Jurassic Rocks of Britain," vol iv, p. 352.

‡ *Proc. Geol. Assoc.*, vol. xiv, p. 353.

§ *Proc. Geol. Assoc.*, vol. xiv, p. 340.

Sections of Kellaway's Sands and Oxford Clay were visited in 1901 on the South Wales Direct Railway at Somerford and Brinkworth.*

The *Corallian Rocks,* originally described by Wm. Smith as "Coral Rag and Pisolite," extend from Highworth to Wootton Bassett, Calne, Steeple Ashton, and Westbury, localities all famous for diversity of rock-types, and most of them for their organic remains.

We have visited the quarries in the Lower Calcareous Grit on Derry Hill, near Chippenham, and in the famous freestone of Calne, where we had evidence of the local abundance of *Hemicidaris intermedia.*† At Steeple Ashton certain ploughed fields have yielded surface-specimens of the well-known corals, *Isastræa, Thamnastræa,* etc., but the Association has not yet gone in search of them.

At Westbury there are fine sections of the oolites of the Corallian, with on top the well-known iron-ore that has been, and still is, extensively worked. We visited the sections on one occasion.‡ The oolitic ironstone is ten feet thick and, like the Upper Corallian beds at Weymouth, contains *Ostrea deltoidea.* Above is the Kimeridge Clay with the same fossil. Lonsdale in early years, and Blake and Hudleston in 1877,§ described in detail many of the sections in the Corallian of Wiltshire.

The *Kimeridge Clay* occupies much of the vale at Swindon, where it has been largely worked for brick-making. Remains of the Dinosaurian reptile *Omosaurus* have been found there. The long familiar *Ammonites biplex* of this formation has been shown by Miss Maud Healey to be the *Ammonites pallasianus* of d'Orbigny, now known as an *Olcostephanus.*|| In the western ends of the Vales of Pewsey and of Wardour the Kimeridge Clay is again exposed in Wiltshire. For the most part it forms the pasture lands for the important dairy farms in the northern and western parts of the county.

Our first recorded excursion into Wiltshire was made in May, 1870, under the guidance of the energetic President, John Morris.¶ In those days more was seen in a given time than is now attempted. It was the end of a three-day "Excursion to Stroud, May Hill and Swindon," and not only was Swindon, with its extensive quarries in the Portland Stone, visited, but

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* *Proc. Geol. Assoc.,* vol. xvii, p. 145; and H. B. Woodward, "Summary of Progress," *Mem. Geol. Survey* for 1898. p. 188.

† *Proc. Geol. Assoc.,* vol. xiv, p. 345.

‡ *Proc. Geol. Assoc.,* vol. xiii, p. 137.

§ *Quart. Journ. Geol. Soc.,* vol. xxxiii (1877), p. 283.

|| *Quart. Journ. Geol. Soc.,* vol. lx (1904), p. 60.

¶ *Proc. Geol. Assoc.,* vol. ii, p. 34.

afterwards the party proceeded to the Sponge gravels of Faringdon in Berkshire.

Swindon, however, furnishes sections that amply repay a day's attention, and, indeed, the quarries of *Portland Stone*, with their irregular capping of *Purbeck*, have attracted many geologists since the days of Fitton, and notably J. F. Blake. Like other calcareous and sandy divisions, the Portland Beds exhibit great diversity in lithological character, and the conventional subdivision of Portland Stone and Portland Sands suitable in Dorsetshire is manifestly inapplicable at Swindon, where we have prominent masses of sand in both Upper and Lower divisions.

A noteworthy incident of the excursion made on Whit-Monday, June 5th, 1876, was the discovery announced by Charles Moore, of Bath, who acted as leader, of "the oldest known true frog" in the Purbeck Beds.* This, however, has not been confirmed, and its occurrence in the Purbeck Beds may reasonably be questioned. At the same time he recorded the occurrence of certain Purbeck Mammalia at Swindon, but the specimens, unfortunately, have since been lost sight of,† and on this account they have been omitted from subsequently published lists.

Traces of Lower Greensand have been noted at Swindon, but no satisfactory evidence of its presence has been obtained. Judging by Fitton's section,‡ the ferruginous sand grouped as Lower Greensand may have been a decalcified portion of the Upper Portland Sands with the hard concretionary masses known as Swindon Stone. In later years the only possible indication of any Cretaceous strata has been that afforded by pipes, or pockets, of ferruginous earth; at best a doubtful testimony.

At the western end of the Vale of Pewsey the Lower Portland Beds have been exposed at Worton near Potterne, and the Upper Beds may be seen by Crockwood Farm to the east. This region was examined by the Association in 1892.§

The Vale of Wardour is rich in geological interest, and in associations with one of the earliest of scientific lady workers, Etheldred Benett, whose home was at Pyt House, to the west of Tisbury. The name is perpetuated in the "Benett Arms," which affords a welcome to the weary geologist. Fitton first made known the detailed structure of this Vale, while J. F. Blake in after years added much to our knowledge of the Portland Beds, and the Rev. W. R. Andrews, for many years rector of Teffont Evias, brought to light many interesting fish remains, beautifully preserved, from the Purbeck Beds, amongst them

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* *Proc. Geol. Assoc.*, vol. iv, p. 544.

† I am informed by the Rev. H. H. Winwood that they are not preserved in the Bath Museum.

‡ *Trans. Geol. Soc.*, ser. 2, vol. iv, pt. 2 (1836), p. 265.

§ *Proc. Geol. Assoc.*, vol. xii, p. 325.

Coccolepis andrewsi and *Macrosemius andrewsi*, named by Dr. A. Smith Woodward.*

In the Purbeck Beds the famous Isopod Limestone was discovered in 1839 by the Rev. P. B. Brodie, who was then curate of Wily (or Wylye), about four miles to the north of the Vale. The Isopod proved to belong to a new Crustacean genus, and the fossil was named *Archæoniscus Brodiei* by Milne-Edwards.

The presence of a Cinder Bed with *Ostrea distorta* at a lower horizon was first noticed by the Rev. Osmond Fisher. The railway cutting at Dinton showed the intimate connection between Purbeck and Wealden, and this section has been described by Mr. Andrews and Mr. Jukes-Browne.†

The large quarries in the Portland Stone at Tisbury and Chicksgrove, and in the picturesque ravine of Chilmark, have been visited by the Association on several occasions. Building stone of different character from that of Portland, on the one hand, or of Swindon on the other, may there be seen.

An excellent account of the geology was given in June, 1881, by W. H. Hudleston, then President, after a visit to the district during the previous Easter. ‡ As he remarked, "No Portland rock in England contains its fossils in such an admirable state of preservation, nor is there any other place where the *Cyrena*-type of beds occurs at the base of the main limestones in such a marked state of development. With reference to this subject, I may observe that what I have called, simply for the sake of illustration, the *Cyrena*-type, that shell being frequently associated with *Cerithium*, represents a peculiar 'estuarine' condition, which was the precursor of the Purbecks." It is noteworthy that *Trigonia* was discovered in the Purbeck Beds by the Rev. W. R. Andrews.§ The so-called "*Cyrena rugosa*" is held by some authorities to be a *Cytherea*, or allied marine genus. This fossil is found in the top Portland stone-beds, and it also occurs lower down in the ragstone above the main building-stone.

A notable feature in the Vale of Wardour, as at Upwey, near Weymouth, is the occurrence of a chalky series, resembling the Chalk formation, with black flints in the Upper Portland Beds.

Hudleston has described and figured some microscopic sections of these flints, and also of flint, or chert, from the Purbeck strata. Examples from both formations contain a few oolitic granules, and the appearances favour the view that the flints resulted from the silicification of calcareous rocks. In some Portland flints many sponge-spicules were found.

Tisbury has long been famous for its "Siliceous madrepore," described in 1729 by John Woodward as the "Starr'd Agate." This Star Coral, the *Isastræa oblonga*, was obtained by Miss Benett on the northern side of Tisbury. The main building-stones of Tisbury consist of "quartzose limestones with some glauconite"; in some layers, as Mr. Hudleston remarked, quartz grains apparently constitute one half of the mass, and the stone-beds have been described as calciferous sandstones or siliciferous limestones.

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* *Geol. Mag.*, dec. 4, vol. ii, 1895, p. 145.

† See *Mem. Geol. Survey*, "Jurassic Rocks of Britain," vol. v, p. 272; and Jukes-Browne, *Geol. Mag.*, dec. 4, vol. x, 1903, p. 252.

‡ *Proc. Geol. Assoc.*, vol. vii, p. 167; see also vol. xviii, p. 153.

§ *Quart. Journ. Geol. Soc.*, vol. xxxvii, p. 246.

Mr. Hudleston pointed to indications of unconformity between Portland and Purbeck Beds in the Vale of Wardour, but I was unable to satisfy myself on this matter, or to see evidence of more than local contemporaneous erosion.* During the excursion in 1903 the Rev. W. R. Andrews maintained that there was no unconformity, and although the lithological change at Wockley was abrupt there was a palæontological transition.†

Striking evidences of unconformable overlap are seen first in the transgression of the *Lower Greensand*, which extends across the Wealden outcrop, near Dinton; while farther north, in the outlier of Lower Greensand at Seend, we see that formation resting on the Kimeridge Clay. More imposing is the great transgression of Gault, Upper Greensand and Chalk across the successive outcrops of the Upper Jurassic rocks, so well seen in the borders of the Vale of Wardour. Here, indeed, we have evidence of a great plain of marine erosion.

The Lower Greensand of Seend has been noted for its iron-ore since 1855, but the amount raised has not been very great. It has recently been again worked on a small scale for smelting elsewhere. The strata in Wiltshire, which comprise pebbly sands and sandy ironstones, were described by Lonsdale, and they have yielded fossils usually at the base. Among these the *Diceras* or *Requienia lonsdalei* was obtained from the country between Calne and Rowde. Other fossils have been recorded from the district by William Cunnington and Mr. G. W. Lamplugh.‡

The *Gault* with *Ammonites interruptus* has been examined by the Association at the Eden Vale brickyard at Westbury, and at Blackland, near Calne. It forms a belt of varying breadth at the base of the Upper Greensand and has been worked for brickmaking at Urchfont, Stert, and other places. *Ammonites benettiæ*, regarded by Mr. Jukes-Browne as a variety of *A. interruptus*, is the prevalent form at Caen Hill, west of Devizes.§

The *Upper Greensand* of Devizes was visited at Easter-time in 1892 under the guidance of Mr. W. H. Bell, of Seend, and Mr. F. J. Bennett.|| The strata are well exposed in the railway

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* *Mem. Geol. Survey*, "Jurassic Rocks of Britain," vol. v, p. 208.

† *Proc. Geol. Assoc.*, vol. xviii, p. 156.

‡ See Jukes-Browne, "Geology of Devizes," *Mem. Geol. Survey*, p. 8.

§ *Proc. Geol. Assoc.*, vol. xii, p. 256.

|| *Proc. Geol. Assoc.*, vol. xii, p. 323.

cuttings at the station and eastwards. They consist in the upper part of green sands with *Pecten asper*, and of greenish-grey sand; and in the lower part of micaceous sand and sandstone, overlying malmstone, a siliceous rock largely made up of sponge-spicules.*

In this neighbourhood there are many deeply-cut roads or hollow-ways, as along the roads to Potterne and Stert; the strata may be seen also in a picturesque ravine at Kilbrooke. The formation extends over the Vale of Pewsey, eastwards to Burbage; and we may note by the way that the Rev. Joseph Townsend was rector of Pewsey when he published his famous work, "The Character of Moses" (1813), in which the more important observations of William Smith were first published.

The Upper Greensand at Maiden Bradley was visited in 1901 under the direction of Mr. J. Scanes.† The party then drove from the railway station at Warminster, one of the most famous of localities, to which, strange to say, only one undescribed visit was made from Frome, on August 3rd, 1890.

If, however, we have failed to give due attention to Warminster, and to the Sponges for which it has been so noted, yet our old associate, C. J. A. Meÿer, discussed the "Warminster Beds" in 1878; Dr. G. J. Hinde has described and figured the Sponges,‡ *Siphonia, Hallirhoa* and others, to which attention had been called by Miss Benett in 1831; and Mr. Jukes-Browne has since cleared up ambiguities in the lists of Warminster fossils, showing that specimens from the Chloritic Marl at the base of the Chalk had been mixed in the older collections with species from the Warminster Greensand.§ There are many pits where the dark green sands and overlying chert-beds may be seen on the southern side of the town; and it is these beds which constitute the true Upper Greensand of Warminster.

The Upper Greensand is well developed along the borders of the Vale of Wardour, in the grounds of Fonthill Abbey, and elsewhere; but the attractions of the Portland and Purbeck beds have hitherto prevented our attention being given to any sections along the higher slopes of the Vale.

The *Chalk* likewise has not occupied much time during excursions in Wiltshire, at any rate when we consider its extent, for it may be said to dominate the geology of the county. For a detailed account of it we must refer to the labours of Mr. Jukes-Browne and Mr. William Hill.||

We have seen something of the Chalk on Etchilhampton Hill, near Devizes, an outlier formed of Lower Chalk, there

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* Jukes-Browne, "Geology of Devizes," *Mem. Geol. Survey*, p. 13.

† *Proc. Geol. Assoc.*, vol. xvii, p. 166; *Quart. Journ. Geol. Soc.*, vol. lvii, p. 96.

‡ Catalogue of Fossil Sponges, Brit. Museum. 1883.

§ *Geol. Mag.*, dec. 4, vol. i, 1894. p. 494; dec. 4, vol. iii, 1896, p. 261; and *Mem. Geol. Survey.* "Cretaceous Rocks of Britain," vol. i, p 240.

|| *Mem. Geol. Survey*, "Cretaceous Rocks of Britain," vols. ii and iii; and *Quart. Journ. Geol. Soc.*, vol. xlv, p. 403. See also Ll. Treacher and H. J. O. White, *Proc. Geol. Assoc.*, vols. xix, p. 378, and xx, p. 508.

about 250 ft. thick, with traces of Melbourn Rock on top. The hill was described by Mr. W. H. Bell* as marking the watershed, whence spring "the head-waters of the Kennet, rising behind Tan Hill and flowing to the Thames; of the Hampshire Avon, rising in the Pewsey Vale and flowing to the English Channel; and of a small stream, rising at the foot of Etchilhampton Hill, which eventually joins the Bristol Avon on its way to the Bristol Channel."

It was mentioned that "on the south slope of the hill are some good examples of terraces, or lynchets, still under cultivation, the retaining walls of which form steep turf banks." To discuss this subject would lead us out of the province of geology, but reference may be made to a paper wherein "The Problem of Lynchets" has been lately discussed by one of our members, Dr. H. Colley March.†

To another member, Dr. H. P. Blackmore, of Salisbury, we have been indebted for much local information respecting the zones in the Upper Chalk. During a visit to Salisbury in 1886 he called attention to the Chalk with *Belemnitella* on Clarendon Hill to the east of the city;‡ and during a subsequent excursion in 1903 the occurrence of the zone of *Actinocamax quadratus* was noted at Britford and East and West Harnham; the *Uintacrinus*-bed of the Marsupite zone was seen in a chalk-pit at the northern foot of Old Sarum, and again near Fisherton; and the Micraster zones were stated to occur near Woodford, at Stratford, and Quidhampton.§ The Chalk Rock has been observed at Homington and Combe Bissett.

The Middle Chalk of Wiltshire has not been specially examined during any of the excursions, but one of the best sections is that described by Mr. Jukes-Browne, at Arn Hill, north-east of Warminster, where the zones of *Holaster planus*, *Terebratulina*, and *Rhynchonella cuvieri* down to the top of the Melbourn Rock, have been exposed.‖

Of Eocene strata, the Reading Beds, London Clay, and outliers of Bagshot Sand occur in Savernake Forest and near Great Bedwyn; and higher beds occur also on the borders of the New Forest. The *London Clay* of Clarendon, near Salisbury, was examined in a railway-cutting during an excursion in 1886, and Mr. Whitaker then remarked that he had never seen any section in that formation which "was anything like so fertile in fossils."¶

On Clay-pit Hill, Chitterne Down, east of Heytesbury, sand and clay were at one time dug. Prestwich observed, in 1857,** sections of mottled clay, and carbonaceous clay, overlain by white sand 10 ft., and white gravel with white-coated flint pebbles and quartz pebbles 6 ft. These strata no doubt belong to the *Reading Beds* and were probably preserved in a pipe or cavity in the Chalk. The white sand was "just the stuff that, when solidified, would form the Druid Sandstone." Miss Benett has recorded the fact that pebbles from the above locality were at one time used to form pavements for grottoes.

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* *Proc. Geol. Soc.*, vol. xii. p. 324.
† *Proc. Dorset Nat. Hist. and Antiq. Field Club,* vol. xxiv, p. 66.
‡ *Proc. Geol. Assoc.*, vol. ix, p. 527.
§ *Proc. Geol. Assoc.*, vol xviii, pp. 146, 160.
‖ *Mem. Geol. Survey*, "Cretaceous Rocks of Britain," vol. ii, p. 453.
¶ *Proc. Geol. Assoc.*, vol. ix, p. 527.
** See *Geol. Mag.* dec. 4, vol. v, 1898, p. 412.

To the scattered blocks of Druid Sandstone, Sarsens, or Greywethers further reference will be made.

It is a remarkable fact that so large a portion of Salisbury Plain is bare of *Clay-with-flints*, and Mr. Jukes-Browne has recently commented on this fact.*

There is no doubt that the true "Clay-with-flints," as described by Mr. Whitaker, the dark reddish-brown clay with unworn flints and often with manganese-ore, that lines the pipes and cavities in the Chalk, is, to some extent at least, a residual product. The larger cavities in Chalk are, however, in most localities infilled with a more or less tumultuous mass of Eocene strata and drifts, and Mr. Jukes-Browne, in dealing generally with the subject, has argued with good reason that the bulk of the clayey material has been derived from Eocene deposits.

Near Marlborough, Prestwich, in 1848, noted the occurrence of ochreous clay and large unrolled flints, and he then remarked: "The clays appear to consist of the breaking up of the mottled clays and sands, the action not long continued. In some cases the clay is free from flints. In others, they occur piled one on another as close as they can be packed."†

Mr. Clement Reid has referred to the disturbance and reconstruction of the accumulations, known as Clay-with-flints, "during the Glacial Period, when floods, caused by the melting of the snow or by rain falling on frozen soil, combined with creep or soil-cap motion farther to mix material which had already been moved.‡

Here we probably have an explanation also of the removal of much Clay-with-flints and of the scattering of the *Greywethers*.

In most instances these concretionary blocks are relics probably from the Reading Beds, which formerly extended over the Chalk of Salisbury Plain and the Marlborough Downs. Similar hardened masses are known to occur in the Reading Beds, but some may have been derived from higher sandy Eocene strata, and Mr. H. W. Monckton, who was President at the time of the visit to Salisbury in 1903, expressed his opinion that the Greywethers of Stonehenge had come from the Bagshot Beds.§

In any case, we may conclude that these great blocks were left scattered over the country when the Eocene strata were so largely washed away, and that in many cases they were stranded in valleys as if by torrential action. It is thus not improbable that their final resting places were fixed during the Glacial period, when the melting of much local snow and ice facilitated their transport.

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* *Quart. Journ. Geol. Soc.*, vol. lxii, p. 132.

† See *Geol. Mag.* dec 4, vol. v, 1898, p. 412.

‡ "Geology of Salisbury," *Mem. Geol. Survey*, p. 64.

§ *Proc. Geol. Assoc.*, vol. xviii, p. 147.

To what extent the country was originally covered with greywethers can be to some extent judged by the large number that must have been broken up for various building and paving purposes, to say nothing of road metal. Ramsay, writing fifty years ago, remarked on their surprising number, and on "their occurrence over many large areas, where they strew the ground so thickly that across miles of country a person might almost leap from stone to stone without touching the ground on which they lie." Nevertheless, he then mentioned that on Marlborough Downs these greywethers "are broken by the hammer into rectangular blocks for paving stones."* This is the case now, and it would be difficult to cross a mile of country anywhere by leaping from one stone to another.

The great destruction that has gone on for centuries has at length induced a public appeal for funds to secure the preservation of some tracts where the greywethers still abound in natural position; and we are glad to record that about 20 acres of ground in Pickle Dean and Lockeridge Dean, near Fyfield, between Marlborough and Avebury, have now been secured to the public.†

The Association has paid several visits to Stonehenge,‡ when discussion has arisen on the other and far-transported blocks that were utilised in the circles. It had generally been overlooked that P. J. Martin in 1857 had suggested that those foreign blocks might have been obtained from the Drift of Selsey, and this view has been supported by Mr. Clement Reid.§

Of relics of ancient man, Wiltshire has afforded the most interesting evidence; but those only of *Pleistocene* age can be referred to now.||

A palæolithic implement fashioned in black flint and labelled "Salisbury, 1846," was long in the possession of my father, Dr. S. P. Woodward, as mentioned by Sir John Evans.¶

It was not until 1863 that Dr. H. P. Blackmore discovered flint implements in the gravel and brick-earth at Bemerton and

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* "Geology of parts of Wiltshire and Gloucestershire," *Mem. Geol. Survey*, 1858, p. 41.

† For zealous services on behalf of the preservation of the greywethers, we are indebted to "The National Trust for Places of Historic Interest or Natural Beauty," to the Wiltshire Archæological and Natural History Society, and the Marlborough College Natural History Society.

‡ *Proc. Geol. Assoc.*, vol. vii, p. 137; vol. ix, p. 529.

§ "Geology of Salisbury," *Mem. Geol. Survey*, p. 69.

|| See "A Sketch History of Marlborough in Neolithic Times," by F. J. Bennett, 1892.

¶ "Ancient Stone Implements, etc." Ed. 2, 1879, p. 627.

Fisherton,[*] and later they were found at Milford Hill and other places. More recent discoveries of palæolithic implements have been made by Mr. S. B. Dixon, of Pewsey, at Knowle Hill, to the north-east of Savernake Forest, at a height of 450 ft. above sea-level.[†]

The gravel on Alderbury Hill, which was examined by Prestwich in 1849, was then said to be "better than any for 20 miles around."[‡] In later years he was disposed to regard the deposit as an outlier of "Westleton Shingle."[§] Since then eolithic implements have been found in the gravel by Dr. Blackmore, under whose guidance a visit was made to Alderbury in 1903[||] In 1898 similar implements were obtained by myself at Brinkworth,[¶] and others were found there in 1901 during an excursion made by the Association.

Those who are inclined to doubt the artificial nature of the eoliths, should at any rate see the instructive series of these stones arranged in the Blackmore Museum at Salisbury, where also are exhibited remains of Pleistocene animals found in association with palæolithic implements, also neolithic stone and bronze implements, and the modern weapons and implements of savages.

Some day the Association should visit Rushmore, the old home of General Pitt-Rivers, on Cranborne Chace, and the Museums of Antiquities which he founded at Tollard Royal and at Farnham, in Dorset.

Early reference is made to Fisherton in a paper read before the Association in December, 1860, by John Pickering.[**] He was an authority on British Mollusca, and was then able to identify twenty-one species of land and fresh-water shells which had been collected at Fisherton by Prestwich and John Brown, of Stanway.[††]

The famous brickfields of Fisherton are about a mile west of Salisbury, and they were visited in 1881 under the guidance of Dr. H. P. Blackmore. There Cave Lion, Hyæna, Mammoth, Rhinoceros, Musk Ox, Reindeer, and Lemming have been found in brick-earth and underlying gravel bordering the river Wily.

Some relics probably of Pleistocene time have been found in fissures of the rocks on the Oolitic uplands. Thus Lonsdale recorded the occurrence of *Rhinoceros* on King's Down to the south-west of Box. The Rev. H. H. Winwood has found subangular and unworn flints and quartz pebbles on Farley Down, near Monkton Farley,* but these may belong to an earlier period, perhaps of late Tertiary planation.

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[*] *Quart. Journ. Geol. Soc.*, vol xx, p. 188.

[†] See E. Willett, *Journ. Anthrop. Inst.*, vol. xxxi, p. 310; C. Reid in "Summary of Progress," *Mem. Geol. Survey*, for 1902, p. 207; H. J. O. White, "Geology of Hungerford," *Mem. Geol. Survey*, p. 104; and Rev. H. G. O Kendall, *Proc. Geol. Assoc.*, vol. xx, p 536 and *Quart. Journ. Geol. Soc.*, vol. lxv, p 166.

[‡] *Geol. Mag.* dec 4, vol. v, 1898. p. 413.

[§] *Quart. Journ. Geol. Soc.*, vol. xlvi, pp. 176, 181.

[||] *Proc. Geol. Assoc.*, vol. xviii, p. 159.

[¶] "Summary of Progress," for 1898, p. 189; *Proc. Geol. Assoc.*, vol. xvii, p. 145.

[**] *Proc. Geol. Assoc.*, vol i, p. 83.

[††] *Quart. Journ. Geol. Soc.*, vol. xi, p. 101; *Proc. Geol. Assoc.*, vol. xvii, p. 245.

In the Lower Avon valley there is much gravel, formed of flat pebbles of Oolitic rocks with sub-angular flints, etc. In them Mammoth has been found at Christian Malford.

In seeking to interpret the sculpture of the area we have, however, to go back, at any rate, to Miocene times, or to a period following the extensive erosion that took place in the Eocene period; and we have to consider the effects on the drainage of the undulations which produced the anticlines of the Vales of Pewsey and Wardour.† The whole subject is full of interest and complication, and local studies must be supplemented by a general consideration of the Tertiary earth-movements, and of the influence exerted subsequently by the conditions brought about during the Glacial period.

The peculiarities in the course of the Bristol Avon have lately been dealt with by Mr. Harmer. Taking its rise in part from streams flowing from the Marlborough Downs, this river yet derives its main affluents from the dip-slope of the Cotteswolds. Some of these flow eastwards to the main stream, which follows a southerly course along the vale near Chippenham and Melksham, then turns westwards by Bradford-on-Avon, and finally traverses the Lower Oolitic range in a northerly direction by a deep valley from Freshford and Limpley Stoke to Bathampton.

Mr. Harmer has suggested that the entrance to the estuary of the Severn in Glacial times may have been blocked by ice, thus opposing the natural drainage and so raising the level of water in the Trowbridge basin as to form a great "Glacial Lake," the overflow of which originated the gorge below Bradford-on-Avon.‡

The explanation is one deserving of all consideration, as it has the merit of explaining features in the drainage system which are otherwise difficult to understand.

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* *Mem. Geol. Survey,* "Geology of East Somerset, etc." p. 162.

† See Strahan, *Proc. Geol. Assoc.*, vol. xiv, p. 405; H. J. O. White, *ibid.*, vol. xvii, p. 399, and "Geology of Hungerford," *Mem. Geol. Survey,* p. 76.

‡ *Quart. Journ. Geol. Soc.*, vol. lxiii, 1907, pp. 483, etc.

CHAPTER XIV.

THE PALÆOZOIC ROCKS OF GLOUCESTERSHIRE AND SOMERSET.

By SIDNEY H. REYNOLDS, M.A., F.G.S.

THE series of strata met with in Gloucestershire and Somerset begins with those near Huntley, described by Dr. Callaway as Longmyndian,* and then ranges with hardly any break from the Llandovery up to the Chalk. There is further, a most interesting set of cavern and other Post-Tertiary deposits, and it may be doubted whether any other part of the British Isles contains such a varied and fossiliferous series of sediments. But it is not merely the number of formations available which renders the geology of this part of England of such special interest, but the fact that many of the deposits, either from excellence of exposure or from some other characteristic, have a far more than local interest. Thus:

1. These Silurian deposits are the only ones of that age in Great Britain known to include contemporaneous volcanic rocks.
2. The Carboniferous limestone sections include those of the Avon gorge and Burrington combe, probably the most complete and finest in the British Isles.
3. The Trias includes the remarkable Dolomitic conglomerate, a deposit confined to the west of England and Glamorganshire.
4. The Rhætic series is better seen than in any other part of England, and the Rhætic bone-bed shows its maximum development.

Other points of almost equal general interest, relative to the Coal Measures and Jurassic series, might be mentioned.

Apart from the stratigraphy, there is much in the scenery, particularly of the Carboniferous Limestone regions, with their gorges, caves and swallets, and of the Cotteswolds, of very special interest; and, finally, from the economic point of view, attention may be drawn to the coal, building stones, celestine and ochre deposits.

Though this chapter deals with the geology of Gloucestershire and Somerset, it has been found convenient not to adhere too closely to the county boundaries, and therefore the Devonian rocks of Exmoor and the Quantocks, though occurring in Somerset, are described with those of Devon.

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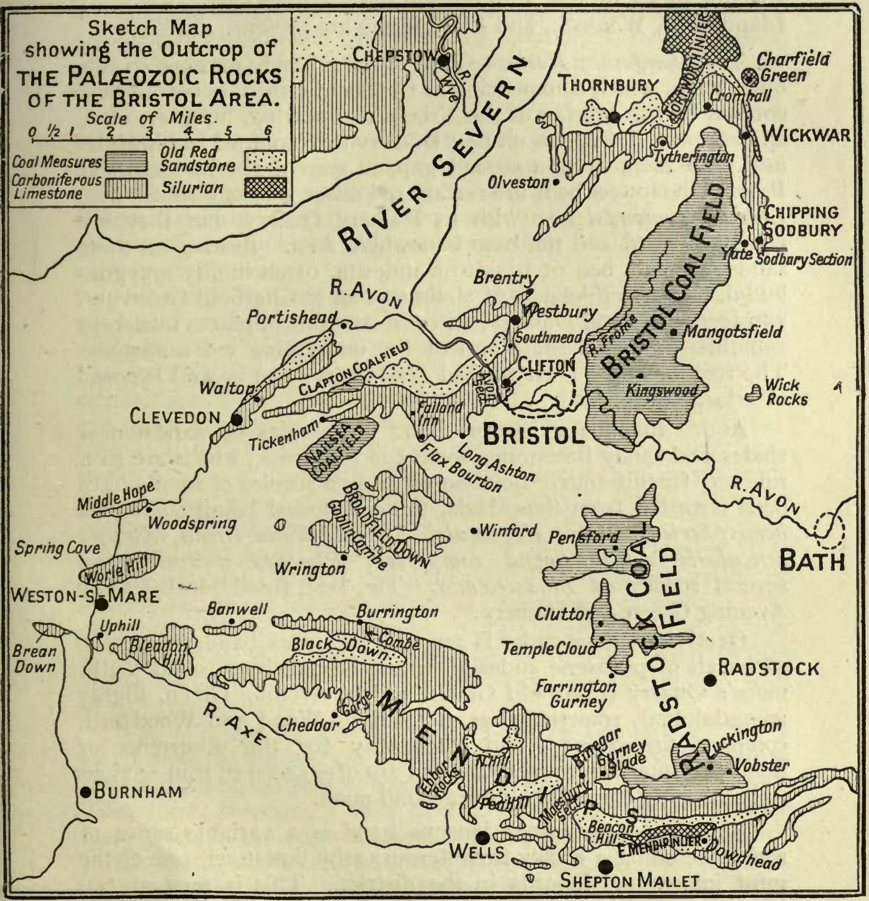
* *Quart. Journ. Geol. Soc.*, vol. lvi (1900), p. 511

SILURIAN.

Silurian rocks appear below the more modern strata in three parts of Gloucestershire and Somerset, where they form the Tortworth, Eastern Mendip, and Mayhill inliers, the two former acquiring a special interest from the fact that they are the only regions in Great Britain in which volcanic rocks of Silurian age are known to occur.*

FIG. 54.



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* See T. Weaver, *Trans. Geol. Soc.*, Ser. 2, vol. i, pt. 2 (1824), p. 317; W. Buckland and W. D. Conybeare, *ibid*, p. 216; R. I. Murchison, "The Silurian System" (1839), p. 454; J. Phillips, *Mem. Geol. Survey*, vol. ii, pt. 1 (1848), pp. 190-198; C. Lloyd Morgan and S. H. Reynolds, *Quart. Journ. Geol. Soc.*, vol. lvii (1901). p. 267; S. H. Reynolds, *ibid.*, vol. lxiii (1907), p. 217; and F. R. C. Reed and S. H. Reynolds, *ibid*, vol. lxiv (1908), p. 512.

THE TORTWORTH INLIER.

This is the largest of the three, and extends from Charfield Green in the south to Tite's Point on the Severn in the north, a distance of rather over eight miles. Exposures are, however, very poor and scanty in the northern half of the area, and the volcanic rocks are met with only in the southern half. Rocks of Llandovery, Wenlock, and Ludlow age are present.

The Llandovery Rocks.—These form a band from one to two miles wide, which commencing at Charfield Green, is before long covered by the overlap of the Trias; reappearing, however, after a brief space, it extends on past Damery to Woodford and Middlemill, and then, after a second gap, is seen again in Eastwood Park. The lowest beds are certain red micaceous sandstones with *Lingula symondsi* met with in Damery Quarry, but they are poorly exposed and the base is nowhere seen. Resting on these sandstones is a bed of basalt or andesite, often highly amygdaloidal, having a thickness of about 60 feet at Charfield Green and 150 feet or more at Damery, where it contains in places numerous xenoliths of baked shale and of the underlying red sandstone. The rock has long been worked at Damery, and is well exposed in a large quarry.

Above this lower igneous band is a series of sandstones, shales and sandy limestones some 500 feet thick, which are as a rule very fossiliferous. Between 60 and 70 species of fossils have been recorded from these beds, the commonest being *Cœlospira hemispherica*, *Orthis elegantula*, *Stricklandinia lirata*, *Atrypa reticularis*, *Strophomena compressa*, *Phacops weaveri*, and several species of *Lindstrœmia.* The best fossil localities are Avening Green and Damery.

Overlying these rocks is an upper igneous band, consisting of basalt or pyroxene andesite, which is sometimes, as at Cullimore's Quarry (Charfield Green) and at Avening Green, highly amygdaloidal, sometimes, as at Daniel's Wood and Woodford, compact, fine-grained, and noteworthy for the occurrence of numerous quartz xenocrysts, which are often seen in thin sections to be strongly corroded by the ground mass.

Resting on the upper igneous band is a variable series of rocks, including a highly fossiliferous, ashy limestone, one of the most interesting deposits in the district. This is seen at two localities—Cullimore's Quarry (Charfield Green) and Middlemill. At Charfield Green a thickness of 2¼ feet of limestone occurs, resting on the highly vesicular top of the basalt. The limestone, which is sometimes gritty, is full of ashy material, as a rule in the form of minute particles, but sometimes in the form of lapilli reaching the length of half an inch or more. Fossils are very abundant, the commonest being *Favosites gothlandica* and

Orthis calligramma; but *Leptæna rhomboidalis*, *Stricklandinia lirata*, and other corals and brachiopods are also common.

Having a similar relation to the basalt, there occurs at Middlemill a band of limestone 3½ ft. thick with large basaltic lapilli scattered through the lower part, but with far less of the finely-divided ashy material than the corresponding deposit at Charfield Green. Corals are extremely plentiful, *Favosites gothlandica* being, as at Charfield, the commonest, but *Heliolites parasitica* and *Lindstrœmia* are also common, as is *Stricklandinia lirata*.

It was formerly considered that the Middlemill trap belonged to the lower band, and that consequently we had at this locality an ashy limestone bearing the same relation to the lower trap band that the Cullimore's Quarry ash bears to the upper band. The relegation of the Middlemill exposure to the upper band does away with the principal reason for regarding the lower trap band as contemporaneous.

Overlying the calcareous ash at Middlemill is a series of grits and shales characterised by the abundance of *Favosites hisingeri* and *Palæocyclus præacutus*. A faunal assemblage also characterised by the abundance of these two forms, but far richer than at Middlemill, occurs in thin bands of calcareous grit associated with shale which are seen overlying the upper igneous band at Daniel's Wood, but no sign of the ashy limestone has been met with here. An identical deposit with *Palæocyclus præacutus* in great abundance is exposed in the southern part of Eastwood Park.

The fauna at all these localities—Cullimore's Quarry, Middlemill, Daniel's Wood, and Eastwood Park—though rather of Llandovery than Wenlock type, is somewhat transitional in character. With the exception of a solitary specimen in the Jermyn Street Museum, no graptolites have been found in any of the Tortworth rocks, and no indications have been met with of a Tarannon fauna.

The Wenlock Rocks.—Rocks of Wenlock age only occupy a small area on the eastern and north-eastern sides of the horseshoe margin of the Bristol coalfield, and are very poorly exposed. They form, however, a wide band all along the western border from Stone in the north to Horseshoe Farm, south of Whitfield, in the south, a distance of about three miles. They consist of a varied series of shales, sandstones, and limestones, the latter rocks forming two fairly well-marked bands which may be followed from Whitfield northwards to near Daniel's Wood and Middlemill, where they are cut off by a thrust fault, which brings the Llandovery and associated lava over them from the east. The best sections of Wenlock rocks are in two old quarries at Whitfield, where somewhat sandy massive limestone with few fossils is overlain by shales and rubbly limestones crowded with *Hallia mitrata*, *Orthis basalis*, and *Orthis elegantula*.

A noteworthy feature of the Whitfield neighbourhood is the occurrence of considerable quantities of celestine in the Wenlock rocks; in Brinkmarsh Quarry, Whitfield, three impersistent bands are seen interbedded in the Wenlock. It has probably been derived from Triassic strata which once overlay the Silurian.

As compared with that of other regions, the Wenlock fauna of the Tortworth region is a scanty one, and it does not seem possible on faunal grounds to compare the lower of the two limestone bands to the Woolhope and the upper to the Wenlock of regions farther to the north.

The Ludlow Rocks.—Typical Ludlow strata, containing the normal fauna and including a representative of the bone-bed, undoubtedly occur in the northern part of the Tortworth inlier at Tite's Point on the Severn, where they were described many years ago by Phillips.* Unfortunately, the thick deposits of Severn mud render it impossible to properly examine the rocks at the present time.

The question as to the occurrence of Ludlow rocks in the southern part of the area has always been a doubtful one; Murchison described a feeble development of Ludlow near Horseshoe Farm at the extreme southern part of the inlier, and the Survey Map shows a narrow band between the Old Red Sandstone of Tortworth and the Wenlock of Whitfield, which widens greatly to the south between Whitfield and Horseshoe Farm. A considerable series of fossils from Horseshoe Farm proved, however, to be rather of Wenlock than Ludlow type, but, on the other hand, at a point close under the Old Red Sandstone escarpment to the south of Daniel's Wood, a faunal assemblage chiefly consisting of lamellibranchs was found, which, in Mr. F. R. C. Reed's opinion,† is rather of Ludlow than Wenlock type. In any case, Ludlow strata if present at all in the southern half of the Tortworth inlier, are very thin and do not show the typical development. Probably the area was upheaved and subjected to erosion during late Ludlow and early Old Red Sandstone times.

THE EASTERN MENDIP INLIER.

Silurian rocks appear below the Old Red Sandstone along the crest of the most easterly of the four anticlinal upfolds forming the Mendip Hills. Their outcrop has a length of rather over three miles, but a width which never exceeds one-third of a mile and is usually very much less than this. The series resembles that of the Tortworth area in including igneous rocks, but differs

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* *Mem. Geol. Survey*, vol. ii, part 1, p. 191 (1848).

† *Quart. Journ. Geol. Soc.* vol. lxiv (1908), pp. 529 and 537.

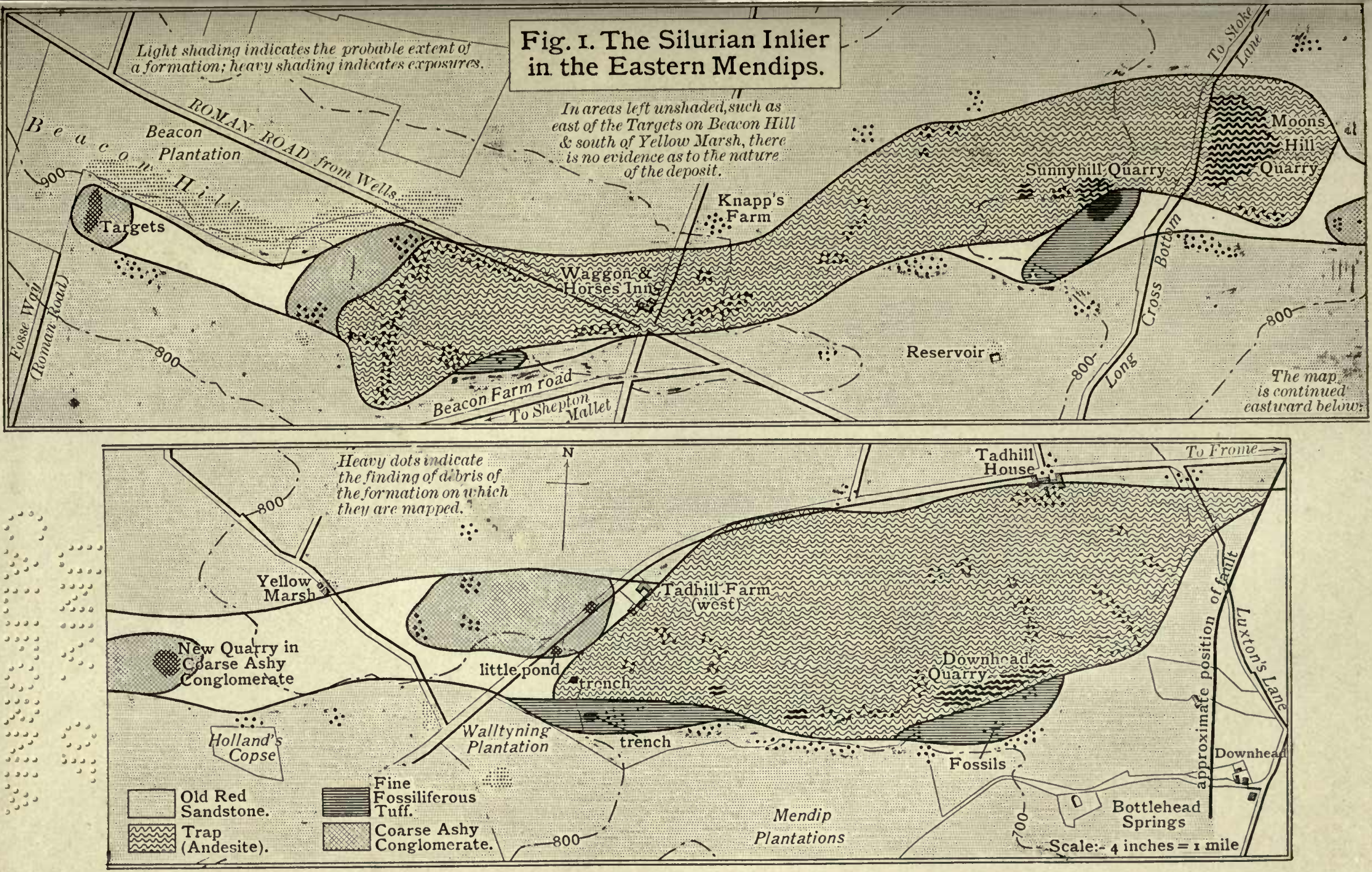

Fig. 1. The Silurian Inlier in the Eastern Mendips.

(Reproduced by permission of the Council of the Geological Society.)

S. H. Reynolds.

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in the fact that hardly any normal sediments have yet been discovered, almost all the rocks being wholly or partially of igneous origin. (See Plate V.)

They include three well-marked lithological types: (a) lava (trap), (b) normal tuff, (c) coarse ashy conglomerate.

(a) *The Lava* (trap).—This is by far the most important rock-type, and till recently was the only one that had been noted. It forms two large masses—a broader eastern mass having a length of just a mile and occurring in the neighbourhood of Tadhill and Downhead, and a narrower western mass having a length of 1⅓ miles and extending from Moon's Hill on the east to near Beacon Hill on the west. Large quarries have been opened in both these masses, the Downhead Quarry in the eastern and the Moon's Hill and Sunnyhill Quarries in the western. Throughout the whole area the lava is singularly uniform in character, being a pyroxene andesite with as a rule both augite and enstatite. The Moon's Hill rock has a specific gravity of 2.72 and the following composition:

Silica	61·16
Calcium oxide	4·90
Aluminium oxide Ferric oxide	23·21
Magnesium oxide	·62
Potassium oxide	2·68
Sodium oxide	4·84
Phosphorus protoxide	·18
Water	2·11
	99·70*

(b) *The Normal Tuff.*—These rocks have been met with in three localities—at Sunnyhill, at Moon's Hill, and farther to the east in the neighbourhood of Tadhill and Downhead. At Sunnyhill there is a fine section showing not far short of 100 ft. of tuff underlying the andesite, and a second band about 25 ft. thick interbedded in the andesite at about 25 ft. from the base. The tuff varies in coarseness, the coarser bands affording perhaps as satisfactory examples of tuff as could well be found. The finer bands contain abundant examples of *Orthis elegantula* and *Rhynchonella davidsoni*, and less commonly, *Lindstrœmia subduplicata*, and other poorly-preserved fossils. At Moon's Hill a band of rather coarse tuff closely resembling that at Sunnyhill occurs in the midst of the trap, but no fossils have been found in it.

In the Tadhill and Downhead regions the tuffs show no permanent sections, but were exposed by trenching at a point near Walltyning plantation on the west, and again at a point due south of Downhead Quarry on the east. The dip at each spot was northerly, and there can be little doubt that a band of tuff underlies the trap of Tadhill and Downhead along the greater part of its southern border. Fossils are very plentiful, especially at Tadhill, where *Orthis elegantula* and *Rhynchonella davidsoni* occur in scores. *Phacops downingiæ* is also common, and, in all, some thirty-six species were met with. The general aspect of the fauna is suggestive of the Llandovery, though certain well-known Llandovery species such as *Stricklandinia lirata* and *Pentamerus oblongus* have not been found. The coarse type of tuff seen at Sunnyhill and Moon's Hill has not been met with in the Tadhill and Downhead regions. The intimate association of these Silurian tuffs with the trap shows that it is not —as was originally supposed—a Post-Devonian intrusion, but a flow of Silurian age.

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* This analysis was made by Mr. J. H. Sturgess in the chemical laboratory at University College, Bristol. It is intended to replace one published in the *Quarterly Journal of the Geological Society*, vol. lxiii (1907), p. 231, on which it was found that, unfortunately, no reliance could be placed.

(c) *The Coarse Ashy Conglomerate.*—This peculiar deposit occurs in two regions—an eastern one lying between the two big trap masses, and extending from Moon's Hill to Tadhill Farm, and a western one occurring in the neighbourhood of Beacon Hill. Throughout the area the coarse ashy conglomerate is very uniform in character, and consists of a matrix composed of ashy particles mingled with quartz grains, enclosing blocks and pieces of rock, large and small, ranging in length up to 18 inches. The great majority of these blocks consist of the local andesite and are thoroughly well rounded, but a certain proportion are subangular. A few pebbles of micaceous grit and sandstone were met with. Little or no sign of bedding could be detected,* the blocks, of all sizes, being jumbled together in a most irregular manner. It has, unfortunately, hitherto proved impossible, in spite of a good deal of excavation, to ascertain the relation of the conglomerate to any other formation, and its method of deposition is by no means clear. The rounded character of the great majority of the blocks seems to demand water action, but the ashy character of the matrix prevents one from regarding the deposit as a normal conglomerate. Possibly it may mark the vents from which the trap and normal tuff were ejected, and in that case the rounding of the blocks may have been brought about by mutual friction either in the throat of the volcano or perhaps partially in the air.†

The only non-igneous deposits of Silurian age hitherto met with in the Eastern Mendips are certain gritty and shaly beds recently exposed, in the region to the south-east of Moon's Hill, in laying a tram line from the Downhead Quarry. Fossils are plentiful, among the commonest being *Leptæna rhomboidalis*, and they indicate that these beds, though in all probability the newest Silurians of the district, are still of Llandovery age.

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* The only good section of this deposit was exposed in a quarry to the south-east of Moon's Hill. This has now (April, 1908) been filled up.

† For a consideration of these and other views see *Quart. Journ. Geol. Soc.*, vol. lxiii (1907), p. 235; also *Proc. Geol. Assoc.*, vol. xx (1907), p. 62.

The May Hill Inlier. (By L. Richardson.)

The Silurian rocks of May Hill[*] form a fault-distorted and denuded pericline, cut off on the east by a great fault that throws the Keuper rocks into juxtaposition with the Silurians, including that subdivision which forms the main core of the hill, the May Hill Sandstone, and that small mass of dubious rock at Huntley that has been dated as Longmyndian.[†]

The May Hill Sandstone contains several fossiliferous layers, rich more especially in specimens of *Lindstrœmia*; but there is little or no indication of the Tarannon Shales, although they may be represented in point of time. The May Hill Sandstone is covered with gorse and bracken, and gives rise to scenery differing widely from the alternating ridge and grass-clothed valley, where Woolhope Limestone, Wenlock Shales, Wenlock Limestone, Ludlow Shales, and Aymestry Limestone prevail.

There is little to be said about the Wenlock Series. The Woolhope Limestone is poorly developed and rarely exposed; the Wenlock Shales are usually visible only in the deeply-cut streams, ditches, and lanes; but the Wenlock Limestone—replete with its characteristic fossils, and, above all, its corals—is exposed in a long line of now mostly abandoned quarries above Longhope. The Ludlow Series comprises Lower Ludlow Shales, Aymestry Limestone, and Upper Ludlow Shales, but the median limestone band is neither extensively nor typically developed. The Upper Ludlow beds are divisible into *Chonetes*- and *Rhynchonella*-Flags as at Ludlow, and graptolites are stated to have been found in the lower division. The Temeside Stage is represented by the Downton Sandstones, which are well developed and extensively quarried at Clifford's Mesne, at the northern end of the May Hill inlier, where certain shaly layers contain *Pachytheca sphærica*, Hooker, in abundance,[‡] but become attenuated at the southern end. The equivalents of the *Lingula cornea*-Beds of the Ludlow district have not been identified in the May Hill area as yet, the deep red marls of the Devonian resting directly and non-sequentially upon the Downton Sandstones in the pit at Clifford's Mesne, where they have been worked for brick-making. This absence of the *Lingula cornea*-Beds, combined with the attenuation of the Downton Sandstones near the railway-cutting towards the southern end of the inlier, prepares us for the non-sequence in the Mendip Hills, where Old Red Sandstone is in apposition with Llandovery or, may be, Wenlock strata. It may be mentioned that of the equivalent of the far-famed Ludlow Bone-Bed only traces have been found,* and those in the railway-cutting that traverses the Silurian ridge between Longhope and Grange Court Stations.

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[*] R. I. Murchison, "The Silurian System" (1839), pp.442-446; J. Phillips, *Mem. Geol. Survey*, vol. ii, part 1 (1848), pp. 181-188; *Proc. Geol. Assoc.*, vol. ii (1871), p. 33; *ibid.*, vol. x (1888), p. 547.

[†] C. Callaway, *Quart. Journ. Geol. Soc.*, vol. lvi (1900), pp. 511-520.

[‡] L. Richardson, *Trans. Woolhope Nat. F. C.*, vol. for 1905, p. 37; *Proc. Cotteswold Nat. F. C.*, vol. xvi, part 2 (1908), p. 108.

THE OLD RED SANDSTONE.

Old Red Sandstone Rocks appear in the core of each of the four anticlinal uplifts forming the Mendip Hills, and though the Broadfield Down anticline has not been eroded down to their level, they are well seen at many points on the greatly-denuded anticline which is traversed by the Avon between Clifton and Shirehampton, and also along the coast between Clevedon and Portishead. Though much obscured by the overlap of secondary formations, they are exposed at a number of points round the horse-shoe-shaped northern outcrop of the Bristol coalfield, especially near Wickwar and between Thornbury and Cromhall. Lithologically the Old Red Sandstone has very much the same characters as in other parts of the West of England, consisting of red and pale sandstones, shales, and marls, with bands of conglomerate and occasional calcareous bands (cornstones). As regards the nature of the conglomerate pebbles, quartz and quartzite prevail, but jasper, porcellanite, and igneous rocks also occur. Many of the pebbles are of distant origin, and Prof. C. Lloyd Morgan believes† that some of them may have been derived from the ancient rocks of St. David's, an opinion in which he is supported by Prof. Bonney. Mr. H. B. Woodward‡ estimates the thickness of the Old Red Sandstone in the Bristol district at about 4,000 ft. The best sections are those seen on the railway lines between Bristol and Portishead and Bristol and Avonmouth respectively, and on the shore to the west of Portishead. None of these, however, show the lower beds.

In the Portishead line on the left bank of the Avon a thickness of some 1,850 ft. is seen between the base of the Carboniferous and a point opposite the mouth of the Trym, where the Old Red is overlapped by the Dolomitic Conglomerate. The beds are divisible into:

2. An upper series of hard grits, often pale and micaceous, with considerable shale beds and very little conglomerate; thickness about 750 ft.

1. A lower series of rather soft red sandstones with only thin shale partings. There is in places a considerable sprinkling of well-rounded pebbles of quartz and quartzite, and in the upper part of the series there is a well-marked band of conglomerate 10 ft. thick resting on a cornstone band 7½ ft. thick. Thickness about 1,100 ft.

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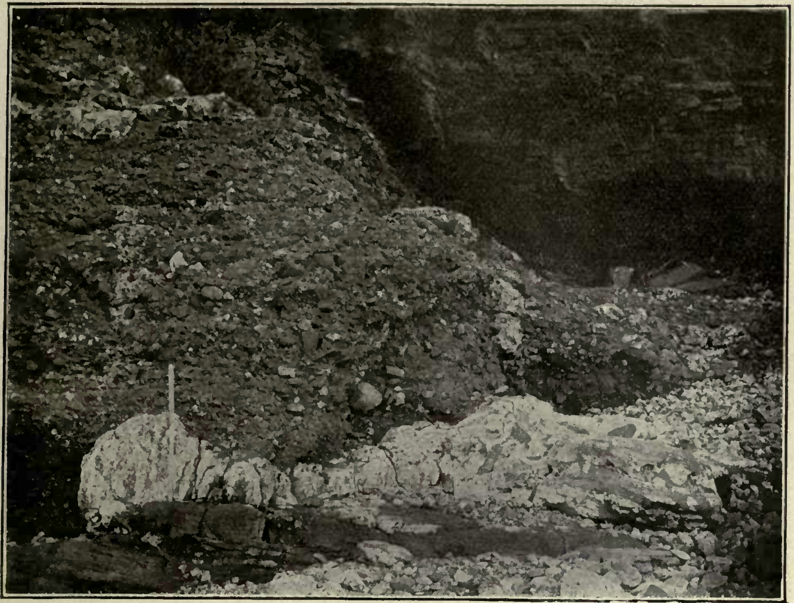
* Sir W. Jardine, "Memoirs of H. E. Strickland" (1858), p. 164; and H. E. Strickland, *Quart. Journ. Geol. Soc.*, vol. ix (1853), p. 8.

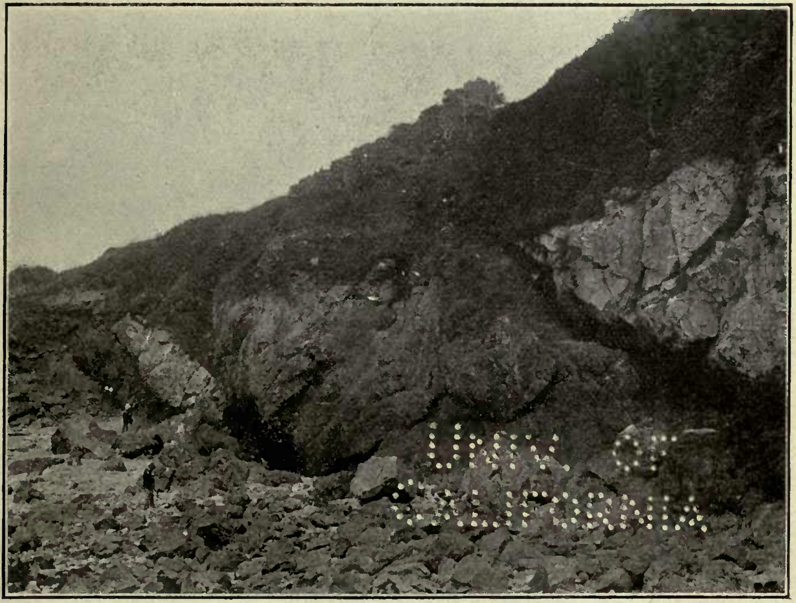
† "Brit. Assoc. Handbook, Bristol," 1898, p. 13.

‡ *Mem. Geol. Surv.*, "Geology of East Somerset and Bristol Coalfields," p. 12.



[*Photo by S. H. Reynolds.*

FIG. 1.—CONGLOMERATE AND LIMESTONE OF OLD RED SANDSTONE AGE, WEST OF WOODHILL BAY, PORTISHEAD.



[*Photo by S. H. Reynolds.*

FIG. 2.—BASALT INTERBEDDED WITH THE CARBONIFEROUS LIMESTONE (HORIZON C_2 BASE), SPRING COVE, WESTON-SUPER-MARE.

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At the top of the Old Red Sandstone a band of pale greenish micaceous sandstone has yielded a considerable number of fish scales. Some of these have been examined by Dr. Smith Woodward, others by Dr. Traquair, who attributes them to *Strepsodus*, both authorities agreeing that they are Rhizodont in character.

In the Avonmouth line on the right bank of the Avon the upper part of the section is not so good as in the Portishead line, much being bricked up. The calcareous and conglomeratic band is, however, well exposed, and occurs at precisely the same level as in the Portishead line. But while on the left bank there is a lower calcareous band overlain by a conglomerate band, on the right bank the whole band is a calcareous conglomerate formed of well-rounded pebbles of quartz and quartzite embedded in a calcareous matrix, the thickness being not far short of 20 ft. S. Martyn* records the finding of fish teeth in the Old Red Sandstone of this section. Farther north, near Shirehampton Station, a splendid section of Old Red Sandstone has recently been exposed by the widening of the line.

Another good section of the upper part of the Old Red Sandstone is seen at Woodhill Bay, Portishead, but the uppermost beds passing into the Carboniferous are not exposed; they are seen, however, near Portishead Dock Station. The most interesting points about the Woodhill Bay section are the occurrence of a considerable number of fish remains and the existence of a markedly calcareous layer. Rhizodont scales in a more or less imperfect state may be obtained in some numbers in a red sandstone mottled with green at about 145 ft. from the top of the section. Fish remains have also been found at other levels. The Bristol Museum contains some fine scales of *Holoptychius* from this locality, and Dr. Smith Woodward has determined scales of *Glyptopomus*, *Bothriolepis*, *Conchodus*, *Ceraspis*, *Holoptychius*, and a Rhizodont from material collected either *in sitû* or from blocks by Mr. E. J. L. Gardiner.† Plate VI, Fig. 1, is reproduced from a photograph of conglomerate and limestone of Old Red Sandstone age west of Woodhill Bay.

Little need be said about the Old Red Sandstone of the Mendips, which is rarely well exposed. The highest beds are seen underlying the basal Carboniferous rocks of Burrington Combe, while the lower beds, consisting mainly of red sandstone, are exposed at various spots round the Silurian inlier to the north-east of Shepton Mallet. Unfortunately, the relations of the Old Red Sandstone to the Silurian are not seen, and at no point is it possible to obtain an estimate of the thickness of the Mendip development of the Old Red Sandstone. It seems not unlikely that the Mendips formed part of a land area during late Silurian and early Old Red Sandstone times, and that we

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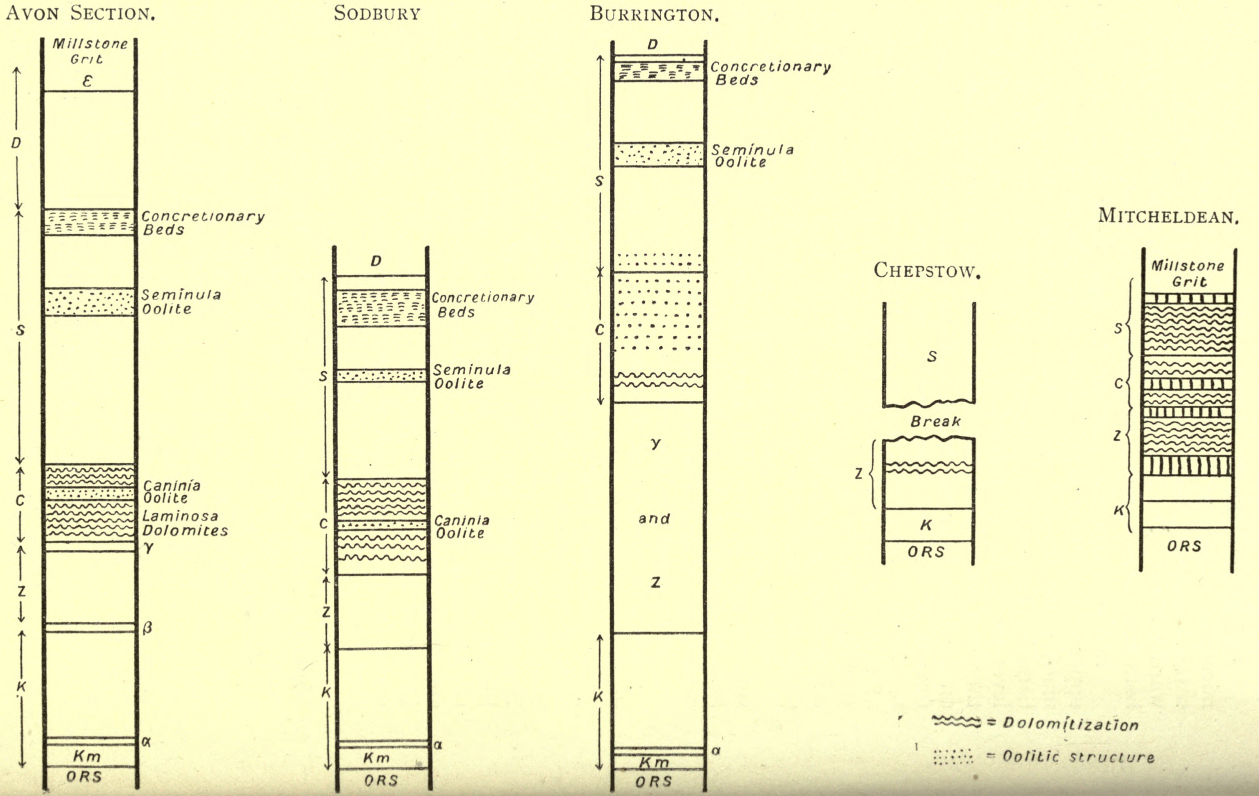
* *Proc. Brist. Nat. Soc.*, new ser., vol. i (1874-76), p. 141.

† *Ibid.*, vol. vii, 1892-94, p. 34.

FIG. 55.—VERTICAL SECTIONS OF THE CARBONIFEROUS LIMESTONE OF THE SOUTH-WESTERN PROVINCE.

(*Partly modified from sections by Dr. A. Vaughan and Dr. T. F. Sibly.*)

Scale 1 *inch*=600 *feet.*



have in the Mendips no time equivalent of the lower Old Red Sandstone beds of regions farther to the north.

A similar explanation will probably account for the curious thinning of the Old Red Sandstone in the Tortworth district, where, to quote Prof. Lloyd Morgan,* "we have the remarkable fact that the beds of this age intervening between the Silurian and Carboniferous forming in Herefordshire a series some thousands of feet in thickness, are to the west of Cromhall reduced to a band of but two or three hundred feet."

CARBONIFEROUS.

THE CARBONIFEROUS LIMESTONE SERIES (AVONIAN).

Owing to the very large amount of work which has been carried out in recent years on the Carboniferous Limestone of the district, and to the occurrence there of two of the very finest and most important sections of these rocks (the Avon and Burrington sections) in the whole British Isles, they will be described somewhat fully.

In describing the sections it is necessary to decide whether to deal with them by localities or by horizons. The former method would simply have meant abbreviating the various published papers and would have presented no element of novelty; the latter method, which has been adopted, will, it is hoped, afford a summary useful to geologists who have not made a special study of the rapidly increasing literature dealing with the Carboniferous Limestone of the south-western province. The following account is, in the main, based upon Dr. Vaughan's papers and those of Dr. T. F. Sibly, and I am further indebted to Dr. Vaughan for personal help and advice and for kindly supplying me with the following table showing the divisions of the Carboniferous Limestone series of the south-western province.†

ZONES AND SUBZONES OF THE CARBONIFEROUS LIMESTONE (AVONIAN) OF THE SOUTH-WESTERN PROVINCE.

KIDWELLIAN = MAIN VISÉAN.	DIBUNOPHYLLUM ZONE. (D)	ε	Horizon of *Productus scabriculo-costatus.*
		D2	Subzone of *Lonsdalia floriformis.*
		D1	„ „ *Dibunophyllum* θ.
			Lower limit defined by entrance of *Dibunophyllum.*
	SEMINULA ZONE. (S)	S2	Subzone of *Productus corrugato-hemisphericus*[1], mut S2 (Main zone).
		S1	Subzone of *Caninia bristolensis*[2] (Persistence of Tournaisian fauna into Viséan).
			Lower limit defined by entrance of *Lithostrotion.*

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* "Brit. Assoc. Handbook, Bristol," 1898, p. 13.

† See A. Vaughan, *Quart. Journ. Geol. Soc.*, vol. lxi (1905), p. 181, and *Proc. Bristol Nat. Soc.*, 4th Series, vol. i, pt. 2 (1906), p. 74; T. F. Sibly, *Quart. Journ. Geol. Soc.*, vol. lxi (1905), p. 548; *ibid.*, vol. lxii (1906), p. 324; and C. Lloyd Morgan, series of papers in the *Proc. Bristol Nat. Soc.*

CLEVEDONIAN.		SYRINGOTHYRIS ZONE. (C)	C2	Subzone of *Cyathophyllum φ.*
			C1	,, ,, Caninoid *Campophyllum.*[3]
				Lower limit defined by entrance of Cyathophylloid *Caninia.*
	TOURNAISIAN.		γ	Horizon of overlap of *Zaphrentis* and *Caninia.* Lower limit defined by maximum of *Caninia cornucopiæ.*
		ZAPHRENTIS ZONE. (Z)	Z2	Subzone of *Zaphrentis konincki.*[4]
			Z1	,, ,, *Spirifer clathratus.*
				Lower limit defined by entrance of *Zaphrentis.*
			β	Horizon of overlap of *Cleistopora* and *Zaphrentis.* Maximum of *Zaphrentis delanoui.*
		CLEISTOPORA ZONE. (K)	K2	Subzone of *Spiriferina* n. sp.[5]
			K1	,, ,, *Productus bassus*
				(including at the base a shallow water phase K_m characterised by *Modiola* n. sp.).[6]

NOTE.—Designation of these fossils in Dr. Vaughan's paper, *Quart. Journ. Geol. Soc.*, vol. lxi, (1905), p. 181 :—

1 *Productus cora*, mut S2.
2 *Caninia cylindrica*, mut S1.
3 *Caninia cylindrica*, mut γ.
4 *Zaphrentis aff. cornucopiæ*, Ed. and H. (non-Michelin).
5 *Spiriferina cf. octoplicata.*
6 *Modiola lata.*

Cleistopora Zone (K) = Lower Limestone Shale of the Survey and many authors.—These beds, the lowest of the Avonian, are best seen in the Avon section, but parts of the zone may be well studied at Burrington, the Maesbury railway section, Mitcheldean, Clevedon, and Portishead, and formerly in the Tytherington and Sodbury railway sections, where, however, they are no longer exposed.

The lower beds (*Modiola* phase, Km) are essentially passage beds from the Old Red Sandstone, and consist of shales with subordinate limestones. They are well exposed in the Avon section in the cuttings on both the Portishead and Avonmouth lines, and at Burrington. The commonest fossils are small lamellibranchs and ostracods, the latter being specially plentiful in certain bands in the Burrington section. Resting on these "Modiola shales" is a band of red, highly crinoidal limestone, the "Bryozoa bed" (horizon *α*), which lithologically forms a marked feature of nearly every section. It is splendidly exposed in the Avon section, well seen at Burrington and Portishead, and occurs also in the Sodbury and Tytherington sections. Microscopical examination of this deposit shows that the name Bryozoa bed is to some extent a misnomer, as the majority of the fossils which used to be regarded as Bryozoa turn out to be crinoidal. Dr. Vaughan remarks * that the lithological character of this rock gives it a definiteness which its palæontological characters scarcely warrant.

The remainder of the *Cleistopora* zone (K1 and K2) resembles Km in consisting of shales with subordinate limestones, but the fauna is more plentiful than in Km and thoroughly marine in character.

The best localities in the Bristol district for the examination of these rocks are the Avon section and the Maesbury railway section in the Mendips. The upper beds are well seen at Portishead to the south of Battery Point, where they are thrown into a series of little anticlines and synclines. The beds are exposed on the shore between the pier and Clevedon Bay, and are poorly seen in the Burrington section. They were formerly exposed in the Tytherington and Sodbury sections, but are now overgrown. The lower beds (K1) are typically developed in the Chepstow and Mitcheldean districts. The lowest bed is the Palate bed, an interesting and well-marked horizon. It is a calcareous conglomerate full of teeth, spines and coprolites of fish, the commonest by far being teeth of *Psephodus lævissimus*. Teeth of *Orodus, Cladodus* and *Petalodus* also occur, and spines of several species of *Ctenacanthus*. Like other bone-beds, the Palate bed is very impersistent in its distribution. At the present time the locality where it may best be studied is the Avon section, where it occurs in the lower of the two Avonmouth cuttings. It was formerly seen by the river side, but this exposure was completely destroyed not long ago by the misguided efforts of a collector. It is not seen in the upper Avonmouth line section or in the Mendips, but it is well-marked at Sodbury.

The best sections of K1 (sub-zone of *Productus bassus*) are the river-side exposure on the left bank of the Avon and the Maesbury section, at both of which localities *Camarophoria mitcheldeanensis* and *Productus bassus* are common.

K2 (sub-zone of *Spiriferina, n. sp.*) is best seen in the most northerly quarry on the left bank of the Avon and on the shore at Portishead and Clevedon, where the zonal fossil, *Cleistopora geometrica*, may be more readily found than anywhere else in the district. Certain bands in the Portishead exposure contain numerous Polyzoa *(Rhabdomeson)* and small gasteropods.

Zaphrentis Zone (Z) = The main part of the Lower Limestone of many authors.—By this time thoroughly deep-water conditions were established, and the beds deposited are mainly massive limestone. One result of this is that they are largely quarried and are consequently splendidly exposed in many parts of the Bristol district, *e.g.*, in the Black Rock Quarry and two northern quarries on the Leigh Woods side of the Avon section, at Wickwar, in the Sodbury and Tytherington sections, at Woodspring and Clevedon, and in the Mendips at the Downside and Waterlip Quarries.

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* *Quart. Journ. Geol. Soc.*, vol. lxi (1905), p. 189.

Dr. Vaughan divides the rocks of the *Zaphrentis* zone as follows, in ascending order :

Horizon β, one of overlap between the *Cleistopora* and *Zaphrentis* zones.
Z1, sub-zone of *Spirifer clathratus*, Vgn.
Z2, ,, *Zaphrentis konincki.*
Horizon γ, one of overlap between the *Zaphrentis* and *Syringothyris* zones.

The *Zaphrentis* zone forms one of the most fossiliferous divisions of the Carboniferous limestone. Among the characteristic and common fossils may be mentioned small Zaphrentid corals, which attain their maximum in Z2, and the brachiopods, *Spirifer clathratus*, *Leptæna analoga*, and *Chonetes hardrensis*, which are far commoner in Z1. Other common brachiopods, such as *Orthotetes crenistria* and *Rhipidomella aff. michelini*, range abundantly through Z1 and Z2.

In the Mendip area there is an acceleration of the coral fauna on the brachiopod fauna as compared with the development in the Avon section. This is specially marked as regards *Michelinia*, which, while rare in the Avon section in Z, is common at this level in the Mendips.*

In the upper part of Z2, in the Black Rock Quarry of the Avon section, are the two famous "fish beds," from which vast numbers of teeth and spines to be seen in all the chief geological collections in England have been obtained. Though a certain number of fish teeth and spines have been found in rocks of this horizon at Burrington, Woodspring, Wickwar, and Portishead, it does not appear that anywhere in the district are the fish beds so well marked as in the Avon section.

The occurrence of dolomitization in the *Zaphrentis* beds of Chepstow and Mitcheldean is a point worth noting, as is the strong development of chert at the top of this horizon and less strongly in Z1 at Burrington.

Horizon γ, characterised by the abundant occurrence of both *Zaphrentis* and *Caninia*, and thus a well-marked horizon of overlap, is one of the most strongly marked levels in the whole sequence, especially in the Mendip region, where large *Caninias* occur in great abundance at Burrington and Brean Down.

Horizon γ is further of considerable interest as being that of the volcanic outbursts of Goblin Combe, Uphill, and Woodspring. At Goblin Combe and Woodspring both ashes and basaltic lava occur ; at Uphill only amygdaloidal basalt, the relations of which to the surrounding limestone are obscure.

While at Goblin Combe the igneous series overlies Horizon γ at the principal Woodspring exposure it underlies these rocks (see table, Fig. 56).*

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* See T. F. Sibly, *Quart. Journ. Geol. Soc.*, vol. lxii (1906), p. 355.

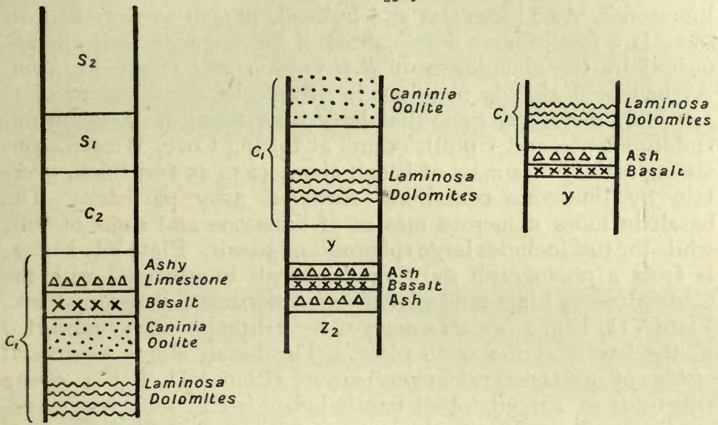
Syringothyris Zone (C).—The lithological characters of the rocks of this zone show, perhaps, more variation than do those of any other. In the Avon section they are divisible into :

1. A lower series of crinoidal and dolomitic limestones, the "laminosa dolomite."
2. A thick bed of oolite, the Caninia or Gully oolite.
3. An upper series of shales with thick bands of dolomite and thin oolites.

Band 2, the *Caninia*, or Gully oolite, is very well marked lithologically, and finely exposed at a number of points in the district, *e.g.*, on both sides of the Avon, at Woodspring and the Southmead Quarries. Other places where this same lithological type occurs at this horizon are the Tytherington and Sodbury sections, Wickwar, Yate rocks, and Walton near Clevedon. It is a white, strongly oolitic limestone, with well-marked joints but very imperfectly-developed bedding planes. Fossils are very scanty, not only in the oolite but in the overlying dolomitized beds. As regards its method of formation, Dr. Vaughan writes :† "Judging by similar deposits of recent age, the *Caninia* oolite indicates perfectly clear and shallow water conditions, such as are associated

FIG. 56.—VERTICAL SECTIONS SHOWING THE POSITION OF THE VOLCANIC ROCKS IN THE CARBONIFEROUS SERIES OF THE BRISTOL DISTRICT.

Scale 1 *inch*=350 *feet.*



WORLE AND WESTON. WOODSPRING. (W. end of ridge.) GOBLIN COMBE.

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* See *Proc. Geol. Assoc.*, vol. xx (1907), p. 155 ; also Sir A. Geikie and A. Strahan "Summary of Progress" for 1898, p. 104; C. Ll. Morgan and S. H. Reynolds, *Quart. Journ. Geol. Soc.*, vol. lx (1904), p. 137 ; *Proc. Brist. Nat. Soc.*, n.s., vol. x (1904), p. 138.

† *Proc. Brist. Nat. Soc.*, 4th series, vol. i, part 2 (1906), p. 96.

with the growth of coral reefs. Further, deposition must have been sufficiently continuous to prevent the formation of well-marked bedding planes, and consequently, when the mass consolidated, cross-joints traversed the whole mass. The dolomites point to the same conditions, for it is probable that the dolomitization which affects recent coral masses is initiated at the surface of the mass and, therefore, practically at sea level." These dolomitized and oolitic beds are, then, clear evidence of shallowing of the water and of disturbed conditions of sedimentation in *Syringothyris* times. There are other local indications of the widespread Mid-Avonian movement afforded by the volcanic series of Spring Cove Weston, and farther west, outside our district, at Pendine near Tenby, by the raising of the area above sea level so that the C beds were not deposited. In the Weston district the beds are not so much dolomitized as they are farther north, the upper beds forming a continuous series of fossiliferous limestones. At Tickenham and Failand, though so near Bristol, there is a fossiliferous development of the upper C beds characterised by the abundance of *Bellerophon* and *Cyathophyllum*. As has been already mentioned, an igneous development of C age and, therefore, somewhat later than those of Woodspring, Goblin Combe and Uphill, occurs at Spring Cove, Weston, consisting mainly of a mass of basalt about 40 to 45 feet thick, overlain by limestone containing scattered ashy particles. The basalt includes numerous masses of limestone and some of tuff, while the tuff includes large spheroids of basalt. Plate VI, Fig. 2, is from a photograph showing the basalt interbedded with the Carboniferous Limestone of the base of horizon C at Spring Cove. Plate VII, Fig. 2, shows a mass of the oolitic limestone imbedded in the basalt at the same place. The basalt shows veins and strings of infiltrated calcareous matter. Plate VII, Fig. 1, shows spheroids of amygdaloidal basalt imbedded in tuff, which, according to Prof. W. S. Boulton, who has described the section, flowed out in a fragmental condition, carrying lumps of basalt with it.*

With the end of the deposition of the C beds Lower Avonian (Clevedonian) time closed, and with the succeeding *Seminula* (S) beds the Upper Avonian (Viséan or Kidwellian) commenced. These beds are characterised by the rarity of the genera *Spirifer*, *Syringothyris*, *Zaphrentis* and *Michelinia*, which played an important part in the preceding beds, and their replacement by *Seminula* and *Lithostrotion*, which rapidly become extremely plentiful.

Seminula Zone (S).—This includes some of the most massive beds of limestone met with in the whole Avonian series of the district; the beds have consequently been much quarried and are

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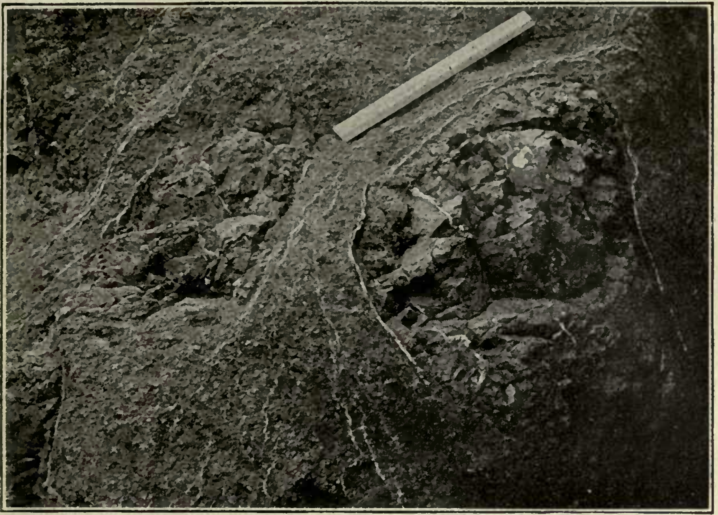
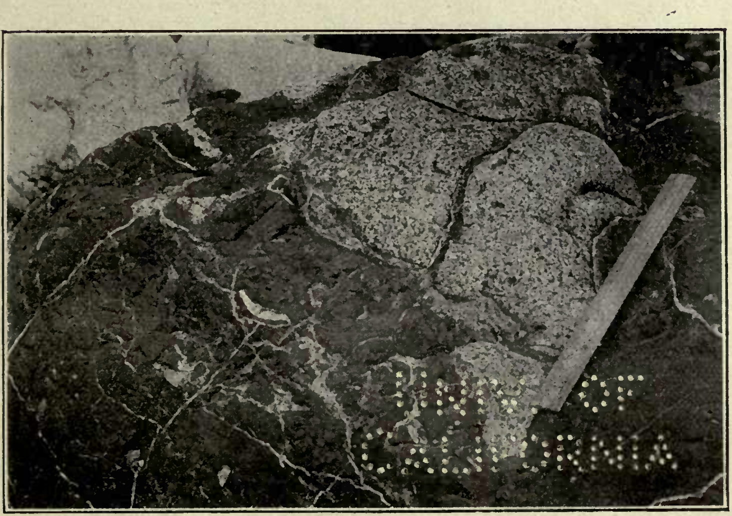
* *Quart. Journ. Geol. Soc.*, vol. lx (1904), pp. 158 to 169; see also *Proc. Geol. Assoc.*, vol. xx (1907), p. 155.



[Photo by S. H. Reynolds.

FIG. 1.—SPHEROIDS OF BASALT IN TUFF—SPRING COVE.



UNIV. OF CALIFORNIA

[Photo by S. H. Reynolds.

FIG. 2.—LIMESTONE MASS IN BASALT—SPRING COVE.

To face page 324.

perhaps better exposed than those of any other horizon. The whole series may be studied in the Avon, Sodbury, Burrington, Cheddar, and Ebbor sections, and the Wickwar Quarries. The finest of these sections are those of the Avon and Cheddar. The lower beds (S1) are also well seen in the Binegar, Gurney Slade and Holwell Quarries in the Mendips, and the upper beds (S2) at Wick rocks, Brentry, and Dod's Quarry near Barrow Gurney.

Lithologically, the beds show several well-marked variations, which may be described in the case of the Avon section. At the base are shales and dolomites with peculiar beds of black compact limestone (China stone) weathering white. These are succeeded by limestone with shaly partings, the whole forming the lower *Seminula* sub-zone, S1. Above comes a massive bed of fine white oolite, the *Seminula*-oolite, which resembles the Gully or *Caninia*-oolite in the strong development of vertical joints and the non-development of bedding planes. The *Seminula*-oolite differs strongly however from the *Caninia*-oolite in being very fossiliferous. At the base of the oolite there is a good development of a peculiar rock type, which may be noted at other levels and localities in the Bristol district; it consists of large, irregular concretions of carbonate of lime formed round shell fragments, etc. Dr. Vaughan describes it as the *Seminula*-pisolite. The upper S beds likewise include a remarkable rock type, that of the "Concretionary beds," which closely resembles the well-known Cotham marble. These beds have their strongest development in the Sodbury section and in a quarry at Chipping Sodbury, but may be well seen on the left bank of the Avon and at the Brentry Quarries. As regards their fossil contents, the *Seminula* beds throughout the greater part of the area are characterised by a great abundance of individuals but by a relatively small number of species, the fauna, as a whole, being impoverished in character. The commonest fossils are *Seminula ficoidea*, which forms well-marked bands at frequent intervals, and *Lithostrotion martini*, which frequently, as in the Avon section and at Wickwar, builds thick beds. Other important fossils common throughout the *Seminula* beds are *Productus corrugato-hemisphericus* and *Chonetes papilionacea*; *Productus semireticulatus*, *P.θ*, and *Caninia bristolensis*, Vgn., are common in the S1 beds of the Avon section. In the Mendip region at Cheddar,* and in the Milton Road Quarries at Weston,† Dr. Sibly describes a highly fossiliferous development of the lower part of S1, characterised by the abundance of *Camarophoria isorhyncha*, *Athyris* cf. *glabristria*, and other fossils. This is unknown in the immediate neighbourhood of Bristol.

Dibunophyllum Zone (D).—In these beds the almost purely calcareous character of the *Seminula* beds gives place to a series of limestones overlain by shales and grits, which, with an included band of limestone, form the "Upper Limestone shale" of the survey and many writers. The rocks are divided by Dr. Vaughan into two sub-zones, those of *Dibunophyllum* θ and *Lonsdalia.* The *Dibunophyllum* θ sub-zone is well exposed in the Avon section, and in two quarries near Flax Bourton Station; the lower beds are also seen in the Sodbury section and quarries, and at Cheddar, Burrington, Gurney Slade, and other places in the Mendips.

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* *Quart. Journ. Geol. Soc.*, vol. lxii (1906), p. 357.

† *Quart. Journ. Geol. Soc.*, vol. lxi (1905), p. 560.

The *Lonsdalia* sub-zone (D2), though no longer well exposed in the Avon section, is seen in the quarry on Rownham Hill, at Wrington, Wick rocks, and at Emborough in the Mendips, but is not often well exposed.

The D beds are characterised by the great number and variety of the corals found. Most English collections contain corals from this horizon, many of them having been obtained during operations for widening the Avon channel. The commonest or most characteristic fossils in the lower beds (D1) are *Cyathophyllum murchisoni*, *Dibunophyllum* θ, *Carcinophyllum* θ, *Syringopora* (2 sp.) and *Alveolites*, together with a large *Productus*, *P. hemisphericus* and *Chonetes* aff. *comoides*. The upper beds (D2) are characterised by *Cyathophyllum regium*, *Lithostrotion portlocki* and *irregulare*, *Lonsdalia floriformis*, and *Dibunophyllum* ψ.

"*Millstone Grit.*"—The highest beds, seen just below the great fault in the Avon section, are hard red grits which have been generally grouped with the Millstone grit; they, however, contain *Lithostrotion*, and Dr. Vaughan includes them as the top beds of his D2 horizon. Above come other red sandy beds with *Productus scabriculus*, forming the horizon ε of Dr. Vaughan, which, though lithologically to be grouped with the Millstone grit, is palæontologically the top bed of the Avonian or Carboniferous limestone series of the Bristol area. Immediately above come very hard, massive grits—the Millstone grit proper. A succession precisely similar to that just described occurs at the Wick rocks, but in the Mendips the succession is doubtful, horizon ε not having been recognised. In the north-western part of our area, at Mitcheldean, Millstone grit conditions come on much earlier than in the Bristol neighbourhood, viz., in S2. These facts show that, as Dr. Vaughan has pointed out, the base of the Millstone grit does not mark a definite horizon, but is variable and dependent on local conditions. But if the method of determining the base level of the Millstone grit by lithological considerations leads to its being drawn at a variety of stratigraphical levels, the same result is produced by taking such a palæontological consideration as the establishment of a fresh-water fauna, for Mr. H. Bolton* has shown that several marine horizons occur in the Lower Coal Measures.

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* *Quart. Journ. Geol. Soc.*, vol. lxiii (1907), p. 445.

As regards the thickness of the Millstone grit, using the term to denote everything between the top of the limestone and the base of the Coal Measures, Mr. H. B. Woodward * gives 1,000 feet as a fair average for the Bristol district, and one recently made by Mr. H. Bolton is in almost precise agreement with this. Before leaving the Millstone grit, mention must be made of the exposures at Ebbor, where it is seen brought in contact with the C and Z beds of the limestone by a thrust fault, and at Winford, where workings for red and yellow ochre occur, which appear to be partly in the Millstone grit, partly in the overlying Keuper.

Throughout the Bristol district the Millstone grit is, in the main, a hard pink quartzite, but in the Mitcheldean district Mr. E. Wethered † describes it as "a loose sandstone of yellow, red and mottled colours, resembling a Triassic sandstone rather than what is understood as Millstone grit in the South Wales, Bristol and Somersetshire coalfields."

COAL MEASURES.

As but little has been written about the Coal Measures of the district in recent years in comparison with the papers devoted to the lower Carboniferous rocks, they will only be briefly referred to. They occur in four regions within the limits of Gloucestershire and Somerset, viz. :

1. The main Gloucester and Somerset coalfield, extending from the Radstock district in the south to the Cromhall district in the north.
2. The small Nailsea coalfield.
3. The still smaller patch near Clapton-in-Gordano.
4. The Forest of Dean coalfield, only a part of which is included in our area.

The general succession in the main Gloucester and Somerset coalfield is as follows :

3. UPPER OR RADSTOCK AND FARRINGTON SERIES, about 2,000 ft. thick.	Sandstones and shales, with about 16 coal seams ; seen at Radstock, Farrington Gurney, Parkfield, Coalpit Heath, etc.
2. MIDDLE OR PENNANT SERIES, about 2,000 ft. thick.	Chiefly sandstone, but containing in places several coal seams ; seen at Mangotsfield, Winterbourne, Yate, Hanham, Temple Cloud, etc.
1. LOWER OR BRISTOL AND KINGSWOOD SERIES, about 2,500 ft. thick.	Sandstone and shale, with a maximum of 26 coal seams ; seen at Kingswood, Long Ashton, etc.

The upper Coal Measures, especially in the neighbourhood of Radstock, have long been famous for the number and variety of

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* *Mem. Geol. Surv.*, "Geology of East Somerset and Bristol Coalfields," 1876, p. 27.

† *Proc. Geol. Assoc.*, vol. x (1888), p. 520.

the fossil plants which they contain. The Radstock workings are further noteworthy in three respects:

1. From the fact that the coal is mined not only through the overlying Trias, but even through the Lias and Inferior Oolite.
2. From the extent to which the pits are free from fire damp. Mr. H. B. Woodward remarks:[*] "In many of the collieries it is almost unknown, and in the seams of the upper series (Radstock and Farrington) it has never been noticed; but in the lower series in the Nettlebridge valley, where the strata are so much disturbed, numerous accidents have taken place from the presence of fire-damp."
3. From the very large amount of faulting which affects the rocks. The disturbances to which the Coal Measures and other rocks have been subjected has given rise to some puzzling points in local stratigraphy, *e.g.*, at Vobster and Luckington, where the Coal Measures are mined below the Carboniferous limestone. Various attempts at explanations, based sometimes on faulting, sometimes on folding, sometimes on a combination of the two, have been brought forward. These were somewhat fully discussed when the Geologists' Association visited the district in August, 1890.[†]

Another region where the relations of the Coal Measures to the older rocks are puzzling is that of Portishead and Clapton-in-Gordano. At the latter place small patches of Lower Carboniferous limestone (Tournaisian) occur, entirely surrounded by Coal Measures. The relations of the two rocks are explained by Dr. C. Lloyd Morgan[‡] by faulting and erosion, while Dr. Vaughan[§] considers that the facts are only to be explained by upheaval and denudation of the area in post-Tournaisian times, resubmergence not taking place till Coal Measure times.[||]

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[*] "Geology of East Somerset and Bristol Coalfields," 1876, p. 35.

[†] See *Proc. Geol. Assoc.*, vol. xi (1890), p. clxxviii, *et. seq.*

[‡] *Proc. Brist. Nat. Soc.*, n. s. vol. v (1886-88), p. 15.

[§] *Quart. Journ. Geol. Soc.*, vol. lxi (1905), p. 232.

[||] See also J. McMurtrie, *Proc. Somerset. Arch. and Nat. Hist. Soc.*, vol. xiii, p 119 and J. Anstie, "The Coalfields of Gloucestershire and Somersetshire," 1873.

CHAPTER XV.

THE NEOZOIC ROCKS OF GLOUCESTERSHIRE AND SOMERSET.

By L. RICHARDSON, F.R.S.E., F.L.S., F.G.S.

IN Gloucestershire and Somerset the Neozoic rocks are those ranging from the Bunter to the Corallian inclusive, the Selbornian, Chalk, traces of Eocene, and Pleistocene deposits—the last including the sporadically-distributed patches of sand of the Cheltenham and Gloucester areas, the so-called "Northern Drift" pebbles of the same parts, the gravel of local origin, the alluvium of the Severn-side, and the Burtle, Peat, and Forest Beds of Somerset. The Kimeridge, Portland, Purbeck, Wealden, Oligocene, Miocene, and Pliocene are absent.

During the fifty years of active existence of the Geologists' Association, parties of its members have visited these counties on several occasions, usually combining the study of the Palæozoic rocks with the Neozoic, and rarely, if ever, restricting their attention to the one.

BUNTER.

Bunter Beds occupy a small area around Bromesberrow,* a village about half-way between Newent and Malvern, and appear from beneath the Keuper rocks in the neighbourhood of the Quantock Hills, encroaching upon or faulted against the Palæozoic rocks of that tract.† In the former area the soft red sandstones belong presumably to the Upper Bunter: no pebble-beds as old as those that occur around the Quantock Hills have been found there, nor have they been proved in the deep borings in or near the Moreton Valley. The "Bromesberrow Beds," as the sandstones are locally called, must apparently be paralleled with the "Upper Sandstones" of the Quantock region.

KEUPER.

In Gloucestershire this series is divisible into two parts—the Lower Keuper Sandstones, or "Waterstones," and the Upper Keuper Marls.

The Lower Keuper Sandstones are well exposed in a quarry at Huntley, in close proximity to the great fault that throws them into juxtaposition with the Silurians of May Hill. In point of time these beds are no doubt represented in the neighbourhood of the Quantock Hills, but are difficult to separate there.

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* *Mem. Geol. Surv.*, vol. ii, pt. 1 (1848), p. 114.

† *Mem. Geol. Surv.*, "The Geology of the Quantock Hills, &c." (1908), pp. 46-64.

There is some variation in the lithic characters of the component beds of the Upper Keuper from place to place.

The highest subdivision, the "Tea-Green and Grey Marls," are best considered separately, for while the "Tea-green Marl" portion is of approximately the same lithic structure throughout this country, the Grey Marls have a less considerable geographical extent. In the Bristol Channel littoral the line of demarcation between the "Tea-green" and "Grey Marls" is not at all sharply defined; indeed, it was on account of the sections in this neighbourhood that the question arose as to whether the "Tea-green" and "Grey Marls" were Rhætic or Keuper.

Originally, Etheridge divided the marls of grey, green, and black colours, which occur between the Keuper Red Marls and the Rhætic Black Shales, into two parts, calling the lower the "Tea-green Marls," and the upper the "Grey Marls." The former he classed with the Keuper, the latter with the Rhætic. Other authors did not feel disposed to accept this ruling, and when the question was again raised in subsequent years by Prof. Boyd Dawkins discovering *Microlestes*' teeth and characteristic Rhætic fossils in the "Grey Marls," Etheridge either forgot or abandoned his old ideas and referred the "Grey Marls," and the "Tea-green Marls" as well, to the Rhætic. Prof. Dawkins, however, had only found the organic remains in the top-portion of the "Grey Marls," and if Etheridge had simply used this information as substantiating his early claim for their Rhætic age, no doubt the matter would have been settled long ago. But he did not: he grouped "Grey" *and* "Tea-green Marls" as Rhætic.

The late Edward Wilson, accustomed to work on the Rhætic Series of the Midlands, could not understand how Etheridge came to the conclusion that the "Tea-green Marls" should be regarded as Rhætic. In the Midlands there is a sharp line of demarcation between them and the overlying Black Shales, and no signs whatever of any transition. By Etheridge lumping the fossiliferous "Grey Marls" with the "Tea-green," and employing the latter term for the joint series, Wilson did not suspect that there were beds on the Bristol Channel littoral, between the "Tea-green Marls" and Black Shales, that were absent from the Midlands, and that, in the former district, constituted true transition-beds, which it was difficult to apportion between the two series. But such certainly seems to be the case: the fossiliferous top-portion of the "Grey Marls"—the Sully Beds—are unquestionably Rhætic, but how far down they extend is a matter that must be decided upon by the downward extent of Rhætic fossils. Up to the present the greatest thickness that has been assigned to them is 13 ft. 1 in., and this was recorded on the Somerset side at Blue Anchor Point. Therefore the "Tea-green and Grey

Marls" that must be given to the Keuper are the original beds thus named, less the Sully Beds.

The "Grey Marl" portion is not co-extensive with the "Tea-green Marls." It is unrepresented, as far as can be seen, in Gloucestershire, but is present in many of the Somerset sections, and on the shores of the English Channel at Culverhole, near Lyme Regis.

Below the Tea-green Marls come red marls, variegated with regular bands and anomalous patches of grey and green tints. Then comes, in the Staunton-Newnham area, at about 215 ft. below the Rhætic, a fairly persistent bed of sandstone, containing *Estheriæ*, ichthyodorulites of a species of *Hybodus*, and the remains of plants. Below, in the same area, come marls again of the same type as those above.[*]

In the Bristol district, however, the lower portion of the Upper Keuper is considerably more arenaceous, and around Chewton Mendip intermittent bands of calcareous sandstone make their appearance. This change as regards lithic structure in the Bristol area is one that might have been expected, for beds of Millstone Grit and Old Red Sandstone must have been exposed while the Triassic rocks were being accumulated, and as what must have been inlet-riven islands are approached, thick conglomerates—the beaches of the period—take the place of the marls, and indicate the former extent of the Keuper waters.[†] "The classic section of a Trias beach" is that at the abrupt turning of the Bridge-Valley Road at Clifton,[‡] and a similar accumulation, resting upon the vertically-placed Old Red Sandstone beds instead of inclined Carboniferous Limestone, is seen in a cliff section between Portishead and Clevedon.[§] The accumulation varies but little from place to place, so that if one section has been seen that is sufficient; but it may be added that in the Mendip Hills it has yielded in the past rich stores of calamine; while at present, at Winford, the earthy variety of hæmatite, raddle, which is so useful in the manufacture of pigments, is worked.

The normal Keuper Marls, sometimes with the Tea-green Marls above, can be seen at The Mythe Tute (Tewkesbury), Wainlode,[||] Garden,[¶] Beachley or Sedbury,[**] and Aust Cliffs,[††] Milton Lane, near Wells,[‡‡] the railway-cutting near Shepton Mallet,[§§] and along the Watchet Coast.[||||]

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[*] See L. Richardson, *Proc. Cotteswold Nat. F.C.*, vol. xv, pt. 2 (1905), pp. 93-100.

[†] See R. Etheridge, *Quart. Journ. Geol. Soc.*, vol. xxvi (1870), pp. 174-191.

[‡] *Proc. Geol. Assoc.*, vol. vi, p. 398.

[§] *Ibid.*, pp. 398-399.

[||] L. Richardson, *Proc. Cotteswold Nat. F.C.*, vol. xiv, pt. 2 (1903) pp. 128-140.

[¶] *Ibid.*, 154-165.

[**] L. Richardson, *Quart. Journ. Geol. Soc.*, vol. lix (1903), pp. 390-395.

[††] R. Short, *Ibid.*, vol. lx (1904), pp. 178-179.

[‡‡] P. B. Brodie, *Ibid.*, vol. xxii (1866), pp. 93-95.

[§§] C. Moore, *Ibid.*, vol. xvii (1861), p. 515.

[||||] Boyd Dawkins, *Ibid.*, vol. xx (1864), pp. 396-412.

No trace of rock-salt has been observed in the marls of these counties, but ramifying veins of gypsum—some of a beautiful pink colour—traverse portions of the cliffs of Aust and West Somerset; while deposits of celestine, near Yate,* and at Abbots Leigh, add to the commercial assets of the Bristol district. The cliffs at Aust† and in West Somerset‡ have been visited by the Association, and so have the interesting celestine workings near Yate,§ where the mineral is first located by long probing rods. The celestine is exported from Avonmouth to Germany in large quantities for use in sugar-refining. In brief, the process consists in the combination of the strontium with the sugar, the removal of the mother-liquor, and the breaking up again of the strontium mono-saccharate.

RHÆTIC.

In Gloucestershire and Somerset the Rhætic Series is more frequently exposed, has a greater superficial extent and thickness, and is more interesting than in any of the other counties. Usually its position between the red ground of the Keuper and the clay-flats of the Lower Lias is indicated by a very marked ridge, at or near the top of which its beds crop out. In addition to their occurrence in this ridge, the beds are also present in a number of small outliers situated at a greater or less distance from the main outcrop.

In West Somerset the series is not far short of 75 ft. in thickness, but towards the Mendip Hills it becomes attenuated; some of the component beds die out, while some or all the remaining deposits become conglomerate. North of those hills it does not regain its former development, and in the railway-cutting at Chilcompton the deposit between the Cotham Marble and Tea-green Marls measures only 10 ft. 4 ins. It is not fully developed at any one locality: if certain divisions are present and well developed, there is at least one that is not. Typically the series is divisible as follows:

LOWER LIAS.	Paper-Shales .	1 ft. at Blue Anchor.
UPPER RHÆTIC.	Watchet Beds .	7 ft. 7 in. at Blue Anchor.
	White Lias . .	20 ft. 8 ins. at Queen Camel.
	"Upper Rhætic" .	7 ft. 8 in. at St. Audries Slip.
LOWER RHÆTIC.	Black Shales .	32 ft. at Lilstock.
	Sully Beds . .	13 ft. 1 in. at Blue Anchor.

The Sully Beds derive their name from Sully on the Glamorganshire coast, where they are full of the oyster *Ostrea bristovi*, and less commonly contain *Pteria (Avicula) contorta* and other

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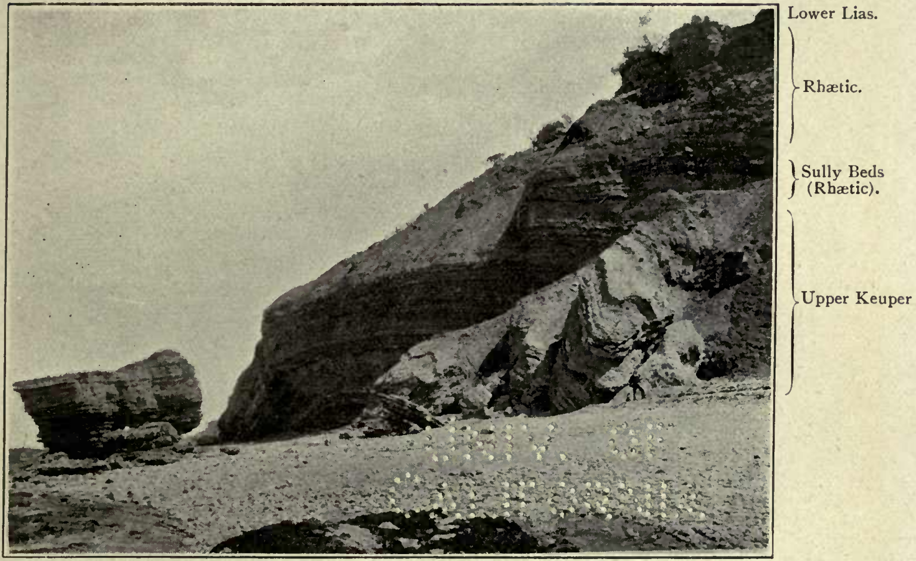
* Excursions, British Assoc. (Bristol, 1898), No. 17.

† *Proc. Geol. Assoc.*, vol. vi (1880), p. 399.

‡ *Ibid.*, vol. xiv (1896), p. 435.

§ *Ibid.*, vol. xvii (1901), p. 149.



[*Photo by L. Richardson.*

VIEW OF BLUE ANCHOR POINT, NEAR WATCHET, WEST SOMERSET.

characteristic Rhætic fossils.* They were formerly regarded as belonging to the Keuper, and were mapped therewith during the recent resurvey, but are unquestionably more closely related to the Rhætic. They have a very limited geographical extent, and are restricted to the Bristol Channel littoral in the neighbourhood of Lavernock and Sully in Glamorganshire, the Watchet coast, with possibly a trace at Dunball, near Puriton.

In early Rhætic times we can picture a stretch of water over the neighbourhood of the Bristol Channel in which the Sully Beds were deposited, and flats of marl near the Palæozoic rocks, encircling or entering valleys in the high ground, but passing away eastwards and northwards into an extensive land of flats and marshes or desert aridness. At all events the neighbourhood of the present Bristol Channel continued to receive deposit longer than other parts. A considerable thickness of black shales and impure limestone and sandstone beds was laid down before the time of formation of the principal Bone-Bed, and at Blue Anchor Point measures 22 feet. This principal Bone-Bed is probably a stratum of slow formation, accumulated during a period when little sedimentation was in progress, but contemporaneous with a gradual and wide-spread subsidence. It may be argued that such bone-beds, as the well-known one at Aust Cliff and the less-frequently investigated one at Blue Anchor Point, are not contemporaneous, but the probability that they are is shown by the occurrence at about the same distance above each of the distinctive *Pleurophorus*-Bed.

Above the horizon of the Bone-Bed in Gloucestershire and Somerset, follow, with considerable regularity, the remaining Lower Rhætic Beds, and the "Upper Rhætic" marls and limestones. Of course some of the *Pecten*-Limestones and sandstone beds are better developed in one place than another, but that is only to be expected.

Throughout the two counties the Black Shales give place to greenish-yellow marls and limestones. North of the Mendip Hills the succession of the component beds of the "Upper Rhætic" is, in ascending order, (4) marls, (3) *Estheria*-Bed, (2) marls, and (1) Cotham Marble or *Pseudomonotis*-Bed. They retain the same characters, or very nearly the same, over the whole area. The *Estheria*-Bed is frequently arborescent, and at Garden Cliff certainly has been mistaken for the Cotham Marble. The *Pseudomonotis*-Bed of that locality, however, is the equivalent of the Cotham Marble. The gradual change is seen in the neighbourhood of Wickwar, where *Pseudomonotis fallax* is very abundant in the "Marble."† The Cotham Marble is continuous over Somerset, but south of the Mendip Hills the beds between it and the Black Shales are not altogether like their equivalents to the north. There are more massive limestones at the base of the Upper Rhætic: *Estheria minuta* var. *brodieana*, the characteristic phyllopod of the *Estheria*-Bed to the north of those hills, is unknown; there are no traces of *Lycopodites;* and frequently the marly beds are of a darker hue. On the Glamorganshire coast at Lavernock there are indications of a partial erosion of the "Upper Rhætic" beds before the deposition of the White Lias, and the same remark is true for Lilstock, but there the particular erosion may be timed more precisely, for it took place after the formation of the Cotham Marble. Signs of interruption in the ordinary quiet run of deposition are to be seen in other parts in the "false Cotham" of Sedbury, and occasionally of Aust Cliff, of the railway-cutting at Somerton, and the *Lithophagus*-bored Cotham Marble of Dundon Hill and elsewhere.

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* L. Richardson, *Quart. Journ. Geol. Soc.*, vol. lxi (1905), p. 386.

† L. Richardson, *Geol. Mag.* dec. 5, vol. i (1904), p. 534. *P. fallax* = *P. decussata* of English authors.

Above the "Upper Rhætic" comes the White Lias proper. It was very well exposed in the railway cuttings near Langport, Somerton, Charlton Mackarell, and Queen Camel, and may still be seen in quarries at the last-named locality, around Long Sutton, near Langport, at places along the Polden Hills, in the Watchet district, at Milton Lane, in the Radstock area, Keynsham, and Bitton. In Mid-Somerset the greater part of the subdivision, and particularly the lower portion, is made up of fairly massive beds, although here and there are more rubbly deposits.

But whilst southwards into Dorset the White Lias retains its Mid-Somerset development, westwards and northwards it becomes reduced in thickness, and, as far as can be seen, it is a case of overlap from south to north. In the railway cutting at Lilliput, near Chipping Sodbury, the Sun Bed—the top-bed of the White Lias—rests directly upon the highest stratum of the "Upper Rhætic," namely, the Cotham Marble;* while farther north, near Wickwar, even the Sun Bed has gone and the *Ostrea*-Beds of the Lower Lias and the Cotham Marble are in apposition. This reduction in the thickness of the White Lias when traced from south to north is not accompanied by an increase in the thickness of the remaining Upper Rhætic deposits. But such is the case when they are followed in a westerly direction, for between the White Lias and the Paper Shales of the Lower Lias come in marly beds, with layers of *Ostrea liassica*, Strickland, to which the name of "Watchet Beds" may be given.

Away from the Palæozoic rocks that must have formed land in Rhætic times, the sedimentaries of the epoch exhibit what Charles Moore would have termed "normal" conditions. But near the ancient land-surfaces they become "abnormal"—of littoral aspect. Interesting deposits, teeming with vertebrate remains, lie horizontally upon the upturned Carboniferous Limestone near the viaduct north of Shepton Mallet,† fill up fissures in the Limestone in the picturesque neighbourhood of Holwell and Vallis Vale,[*] and, markedly conglomeratic, crop out in the sides of the lanes near Butcombe, appearing from beneath the Lias that caps the outliers.

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* S. H. Reynolds and A. Vaughan, *Quart. Journ. Geol. Soc.*, vol. lx (1904), p. 195.

† De la Beche, *Mem. Geol. Surv.*, vol. i (1846), p. 278.

In Gloucestershire the Rhætic sections worth visiting are at Wainlode Cliff, Denny Hill,[†] Garden Cliff, near Westbury-on-Severn, Sedbury, Aust, and New Clifton;[‡] and in Somerset at the railway-cutting, Chilcompton, the Emborrow Fuller's Earth Works,[§] Hapsford Mills, Holwell (Rhætic "dykes"), Shepton Mallet (railway- and road-cuttings), Milton Lane, near Wells, the railway-cutting at Dunball, near Puriton, in places on the Polden Hills, and at Lilstock, St. Audries Slip,[||] and Blue Anchor Point in West Somerset (Plate VIII).

Nearly every section of the Rhætic Beds has its own particular features. For example, at Wainlode Cliff the passage may be studied from a true bone-bed into a non-vertebratiferous sandstone. Denny Hill, near Minsterworth, is notable for the absence of the *Pullastra*-Sandstones, which are well developed at Garden Cliff. Garden Cliff is indeed characterised by these beds, and in addition is noteworthy as being the first place in England where star-fish were obtained from the Black Shales. The *Estheria*-Bed, with its arborescent markings, and the bed crowded with *Pseudomonotis fallax*, are also well known. Aust Cliff is classic on account of its Bone-Bed, with rounded lumps of "Tea-green Marl" and numerous *Ceratodus* teeth. Sedbury Cliff, on the opposite side of the Severn, is almost a replica of Aust, and is noticeable for its "false Cotham"; while the West Somerset sections are specially famed for the Sully Beds, the presence of infra-Bone-Bed Black Shale deposits, the Bone-Bed, the *Pleurophorus*-Bed, the relations of the "Upper Rhætic" and White Lias beds, and the Watchet Beds.

LOWER LIAS.

At Wainlode and Garden Cliffs, and at Blue Anchor Point, the lowest bed of the Lias is shale—the Paper Shales. Frequently, however, they are absent, and the *Ostrea*-Beds near Wickwar repose directly upon the Cotham Marble, and in Mid-Somerset upon the White Lias.

From Tewkesbury to Keynsham the lower portion of the Lower Lias is essentially a limestone formation. Layer after layer of limestone goes to make up the thick series that formerly was so extensively worked near Tewkesbury, Coomb Hill, Wooldridge Hill, near Gloucester, around Elmore, and on the opposite bank of the Severn at Chaxhill, in the clearings in the woods between Wickwar and the Cotteswold Hills, at Horfield, Bitton, Keynsham,* and Bedminster Down, and finds its equivalent in the thirteen miles of monotonous cliffs that form part of the southern coast of Glamorganshire between Penarth and Sutton, and that pass westwards into the peculiar bastard freestones of the latter locality and the conglomerates of Southerndown.

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[*] C. Moore, *Quart. Journ. Geol. Soc.*, vol. xxiii (1867), pp. 482-491.

[†] L. Richardson, *Proc. Cotteswold Nat. F.C.*, vol. xiv, pt. 3 (1903), pp. 254-256: E. T. Paris, *Ibid.*, vol. xv, pt. 3 (1906). pp. 263-266.

[‡] W. H. Wickes, *Proc. Geol. Assoc.*, vol. xvi (1900), pp. 421-423.

[§] C. Ll. Morgan and S. H. Reynolds, *Proc. Bris. Nat. Soc.*, n.s., vol. ix (1899), p. 109.

[||] Vert. Sect., *Geol. Surv.*, sheet 47, No. 6. See also Etheridge, *Proc. Cotteswold Nat. F.C.*, vol. vi, pt. 1 (1871), pp. 35-48; and Rev. H. H. Winwood, *Proc. Geol. Assoc.*, vol. xiv (1896), pp. 378-388.

South of the Mendip Hills there is a similar dual division of the Lower Lias into limestone and clay, and the cliffs of Glamorganshire have their counterpart in the rugged coast immediately to the west and east of Watchet harbour.† But while the limestones are of the normal type away from the region of the Mendip Hills as along the Polden Hills, around Langport, Somerton, Queen Camel, and Evercreech in their immediate neighbourhood, and at Broadfield Down nearer Bristol, as well,‡ they become influenced by the detrital matter that was worn from those Palæozoic land-masses during the time of formation of the Liassic beds. Thus on Harptree Hill, near a considerable patch of Old Red Sandstone, they are very siliceous; while at the villages of the same name—Downside on the southern slopes of the Mendips, and Downside on Broadfield Down—they partake of the nature of the Sutton Stone, being massive-bedded, sparry freestones. On Harptree Hill the cherty Lias is now seen only in the remarkable "pot" or "swallow-hole" on the east side of the road about half-way between East Harptree and the Castle of Comfort,§ and is mainly of *Megastomatos* hemera. The bastard freestone of Downside, near Shepton Mallet, is worked in but one quarry, that near Ham Farm, Bowlish, but is well seen in a quarry by the side of the railway line near the viaduct north of Shepton Mallet; while that at the Broadfield Down, Downside, is not quarried at all now, although it is still well exposed in the old workings near Downside House.

Leaving out of consideration for the present what may be termed the "Radstock Area," clays constitute in Somerset the main portion of the remainder of the Lower Lias stage.

In Somerset, excluding the area named above, sections in the upper beds of the Lower Lias are few and far between. Clays of *Oxynoti-raricostati* hemeræ were exposed in the railway-cutting at Cannard's Grave, near Shepton Mallet,‖ and again in

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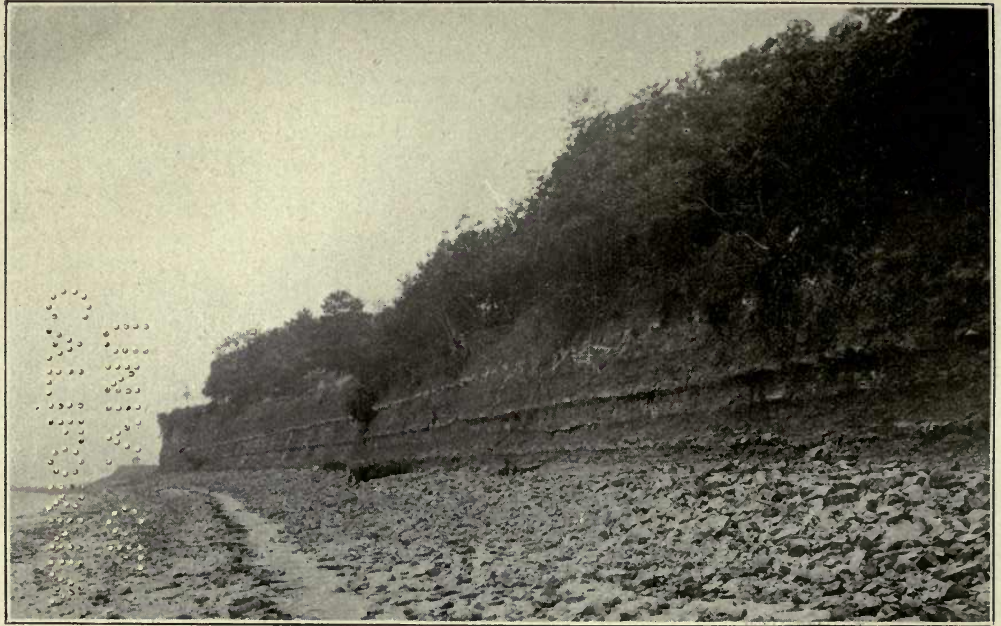
* A. Vaughan and J. W. Tutcher, *Proc. Brist. Nat. Soc.*, n.s., vol. x, pt. 1 (1903, issued for 1901), p 3.

† *Mem. Geol. Surv.* "The Jurassic Rocks of Britain," vol. iii (1893), pp. 91-97.

‡ L. Richardson, *Proc. Cotteswold Nat. F.C.*, vol. xiv, pt. 1 (1901), pp. 69-73.

§ *Mem. Geol. Surv.* "Geology of East Somerset and the Bristol Coalfields" (1876), pp. 105-108.

‖ *Mem. Geol. Surv.* "The Jurassic Rocks of Britain," vol. iii (1893), p. 86.



UNIV CALIF

[Photo by J. S. Daniels.

THE LOWER LIAS AT HOCK CLIFF, FRETHERNE, GLOUCESTERSHIRE.

(Reproduced by permission of the Council of the Cotteswold Naturalists' Field Club.)

the banks of the Brue above Hornblotton Mill, near Castle Cary.*

North of the Bristol area the clay deposit rapidly thickens, and beyond Berkeley spreads out and occupies the greater portions of the broad vale land between the ridge formed of the basal limestones and the initial part of the slope of the Cotteswold Hills.

The low river-cliff at the Hock Cliff, Fretherne, is the first exposure of the supra-limestone clays after leaving Bitton. Here the topmost limestones of *Marmoreæ* hemera are just visible at low tide, and are succeeded by nodule-lined clays of *Rotiformis-gmuendensis* and possibly later hemeræ.† (Plate IX) Farther up the river is the low cliff at Maisemore, composed of clays—crowded along certain horizons with foraminifera and ostracoda—and limestone bands replete with *Isocrinus* ossicles.‡ More inland, the clays of *Oxynoti-armati* hemeræ have been excavated at the Gloucester Gas Works, and the *Capricornus*-Beds—with their richly fossiliferous bands of impure limestone—at Stonehouse and Robins' Wood Hill. Near Cheltenham, only four pits are now in work, namely, at Folly Lane *(Raricostati-armati)*, near Leckhampton Station *(Valdani)*, Webb's pit at the foot of Battledown Hill, and at Shackel's Pike on the Cemetery Road.§ Pilford, where the *Capricornus*-Beds were a short time ago so well exposed, is now abandoned, and the once celebrated pits at Bishop's Cleeve—where *Hippopodium ponderosum* was so abundant—can scarcely be located. Dumbleton pit *(Striati-capricornus)*, and that at Greet *(Capricornus)* are also overgrown, and had it not been for the making of the Cheltenham and Honeybourne line during the past few years our knowledge of the fauna of the clay beds of this part of Gloucestershire would have been scanty in the extreme. As it is, it is known that in North Gloucestershire there is a great thickness of clay; precisely how thick it is difficult to say, but certainly some hundreds of feet, and dating from *Rotiformis* to *Capricornus* inclusive.

Compare this with the remarkable development of the Lower Lias that obtains in the Radstock area.‖ In one section in that neighbourhood, namely, at Writhlington (Plate X), there is Inferior Oolite at the top and White Lias at the bottom, while in the intervening 17 ft. of limestone, not clay be it noted, are deposits of *Planorbis*, *Armati* (with derived *Raricostatum*-Bed fossils at the base), *Jamesoni*, *Valdani*, and *Striati* hemeræ. The rubble of Inferior Oolite is derived from the weathering of Upper *Trigonia*-Grit, Upper Coral-Bed, and basal Doulting Stone, and has yielded *Clypeus agassizi*, *Collyrites ovalis*, *Clypeus hugi*, *Acanthothyris spinosa*, *Rhynchonella subtetrahedra*, etc.

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* *Ibid.*, p. 84.

† W. C. Lucy, *Proc. Cotteswold Nat. F.C.*, vol. viii, pt. 2 (1884), pp. 131-133 L. Richardson, *ibid.*, vol. xvi, pt. 2 (1908), pp. 135-142.

‡ L. Richardson, *ibid.*, vol. xv, pt. 3 (1906), pp. 259-262.

§ L. Richardson, "A Handbook to the Geology of Cheltenham and Neighbourhood" (1904), pp. 44-47; and *Proc. Geol. Assoc.*, vols. xv, p. 181, and xx p. 514.

‖ R. Tate, *Quart. Journ. Geol. Soc.*, vol. xxxi (1875), pp. 493-510.

Space prevents a longer notice of the Lower Lias of this interesting neighbourhood; suffice it to say that in its rocks is chronicled the tale of rapid and slow deposition, elevations and subsidences, and erosions innumerable.

A hurried inspection of the Lower-Lias cliff at Fretherne, and the possible collecting of a few fossils from the bottom beds of the Lower Lias at Garden and Aust Cliffs, is nearly all that the Association has done amid the Lower-Lias rocks of Gloucestershire. The clay-pit at the foot of Battledown Hill has been twice visited, in 1897 and 1908; but those at Robins' Wood Hill and Stonehouse await investigation. The Radstock area, about which both Tate and Tawney* have written, and over which so many geologists have roamed, was visited in 1880, but the little knowledge possessed concerning the apparently unsystematic distribution of the various zones may be read in the statement that "even in proximate quarries different zones being totally absent, so that the Middle Lias lies on the Lower in a kind of 'false unconformity.'"† It was again visited in 1909.

MIDDLE LIAS.

The Middle Lias succeeds to the Lower, and—adopting the Geological Survey classification—typically consists of a lower or sandy shale division, and an upper or Marlstone division. In Gloucestershire north of the Stroud area springs indicate where the sandy shales and less pervious Lower Lias clays meet; while they frequently issue from the top of the Marlstone.

Starting in the neighbourhood of Bourton-on-the-Water, the Marlstone forms a well-defined platform on the eastern side of the Vale of Bourton; is traceable from Stow-on-the-Wold northwards to Batsford, where it gives rise to a long promontory; all around Ebrington Hill, and then southwards—following the sinuosities of the Cotteswold Hills—to the neighbourhood of Stroud. Sections of the Marlstone are by no means numerous; there is one below Iccomb Camp, on the slope of the hill facing Maugersbury, near Stow; another in a deep cutting at Chipping Campden,‡ several on Ebrington,§ Alderton, Bredon,|| and Churchdown Hills;¶ an exposure on Cleeve Hill, and traces on Robins' Wood Hill; but that is about all. The faunal and lithic characters of the rock along the eastern side of the

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* E. B. Tawney, *Proc. Bristol. Nat. Soc.*, n.s., vol. i, pt. 2 (1875), pp. 167-189.

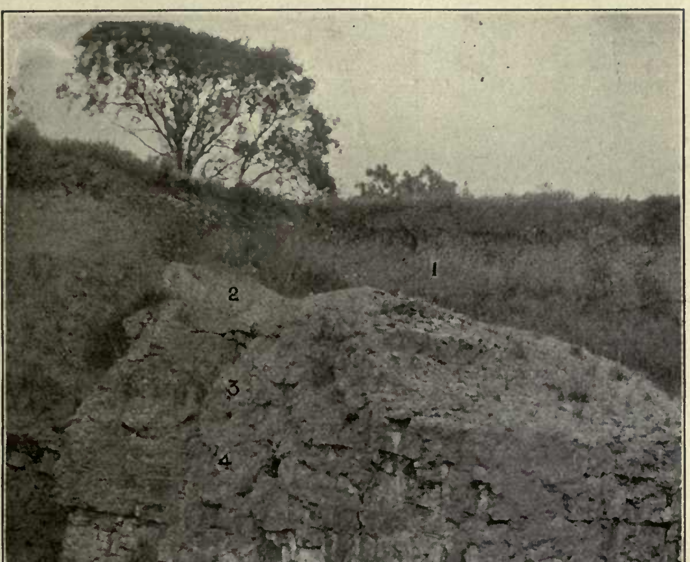
† *Proc. Geol. Assoc.*, vol. vi, p. 402; and see vol. xxi, p. 222.

‡ L. Richardson, *Proc. Geol. Assoc.*, vol. xviii (1904), p. 393.

§ L. Richardson, *Proc. Cotteswold Nat. F.C.*, vol. xvi, pt. 2 (1908), p. 130.

|| L. Richardson, *Trans. Woolhope Nat. F.C.*, for 1902, pp. 63 and 66.

¶ F. Smithe, *Proc. Cotteswold Nat. F.C.*, vol. vi, pt. 4 (1876), p. 349.



[Photo by J. W. Tutcher.

WRITHLINGTON QUARRY, NEAR RADSTOCK, SOMERSET.

1. *Striatum*-Clays (5 ft.) with rubble of Inferior Oolite above; 2. *Valdani*-Beds (1 to 2 ft.); 3. *Jamesoni*-Beds; 4. *Armatum*-Beds (with fossils of *Raricostati* hemera remanié at the base); 5. *Planorbis*-Zone (5 ft.); 6. White Lias.

Cotteswold Hills are fairly constant. The rock-bed is mainly of *Spinati* hemera, fossiliferous, and slightly ferruginous. At Bredon and Alderton it is less ferruginous, but equally fossiliferous. At Churchdown Hill there is a hint of a change in the deposit of *Spinati* date. It is less compact and more sandy, and when Stroud is reached it is found that the *Spinatum*-bed is yet more sandy, and that it is two separate beds of *Margaritati* hemera that constitute the local Marlstone.* At Cam, near Dursley, the two marlstone beds of the Stroud area have conjoined, and with the *Spinatum*-bed form a massive bed of rock at least 15 ft. thick, mainly of *Spinati* hemera, but partly of *Margaritati*, with indications of the "Transition-Bed"† *(Acuti)* of the Midlands above.

The Marlstone continues its course southwards by way of Wotton-under-Edge, but at Dyrham it becomes indistinct and is rarely traceable in the neighbourhood of Bath. It is apparently absent from Timsbury Sleight. In the great Vobster Quarry the bed that represents the deposit that contains the phosphatic concretions is joined on to the well-planed surface of Carboniferous Limestone, and, like the four or five feet of succeeding brown limestones, is richly fossiliferous. Moore would probably have called the higher beds Marlstone. On the south side of the Mendip Hills we find the true Marlstone again at Mays (or Maes) Down—a thick and typical bed mainly of *Spinati* hemera.‡ As such, it is continuous in the crescentic range of low hills by Sherborne to Ilminster,§ and forms noticeable platforms in the outliers of Pennard Hill, Glastonbury, and the more distant Brent Knoll.‖ The Marlstone exposed in the quarry near West Pennard is crowded with ammonites, and the roads around are literally metalled with them.

Apart from road-metal and for local building purposes, the Marlstone of Gloucestershire and Somerset has no commercial value. The only attempt to work iron, to the writer's knowledge, was in the combe running eastwards from Nibley, near Wotton-under-Edge; but it proved futile. To the palæontologist, however, it is of great interest, more especially around Ilminster.

The Association has visited the principal sections of the Marlstone, namely, those at Chipping Campden, Stroud, and South Petherton; but it still remains for them to view the underlying sandy shales, which are so well exposed at Stonehouse and Robins' Wood Hill.

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* E. Witchell, "Geology of Stroud, etc." (1882), p. 17.

† C. Moore, *Proc. Somerset Arch. and Nat. Hist. Soc.*, vol. xiii (1867), p. 140.

‡ L. Richardson, *Geol. Mag.*, dec. 5. vol. iii (1906), p. 368.

§ C. Moore, *Proc. Somerset Arch. and Nat. Hist. Soc.*, vol. xiii (1867), p. 119 *et seqq.*

‖ H. B. Woodward, *Mem. Geol. Survey*, "The Jurassic Rocks of Britain," vol. iii (1893), pp. 207-208.

UPPER LIAS.

The Upper Lias varies considerably in lithic characters and thickness when traced through Gloucestershire and Somerset.

On the borders of Gloucestershire and Oxfordshire it is a clay formation from top to bottom, and at Little Rissington (Fig. 57) measures some 100 ft.[*] In the North Cotteswolds there is a trace of Cotteswold Sands above the clay, but no Cephalopod-Bed has yet been seen. At Bredon Hill the deposit is all clay again, of considerable thickness, and part of it at any rate equivalent to certain portions of the Cotteswold Sands and Cephalopod-Bed of the Dursley district.[†] At Cleeve Hill the *Scissum*-Beds rest directly upon clays; but near the Rifle Range close to the Seven Springs, near Cheltenham, there is a trace of Cotteswold Sands again. At Crickley Hill there is some sand, but there is a thin clay-bed above, which—occurring at the base of the *Scissum*-Beds and throwing out water—gives the impression that no sand-deposit is present. At Birdlip such is really the case: there are no Cotteswold Sands there; but at Cooper's Hill they come in again; form the conical portion of Robins' Wood Hill, except the actual cap; and are thence continuous, in increasing thickness, right away to Bath. In the neighbourhood of Dursley the Sands are of *Lilli-variabilis* hemeræ,[‡] and are clearly exposed below the *Striatulum*-niveau in the Wotton-Hill section. But at "The Springs," near Dodington, this niveau comes *in* the Sands, and at Timsbury Sleight, in Somerset, below. The Sands therefore are of different date: the Cotteswold Sands are pre-*Striatuli;* the Midford Sands, post-*Striatuli*—indeed, post-*Struckmanni.*

To finish with Gloucestershire first, however, below the Cotteswold Sands, from Cooper's Hill southwards, are blue clays. They are thickest in the north, being replaced by an arenaceous deposit as they are traced southwards. At Stinchcombe Hill the equivalent of the "Transition-Bed" of the Midlands, a deposit of *Acuti* hemera was discovered by Messrs. B. Thompson and W. D. Crick just above the Marlstone,[§] but that is the only record of it in Gloucestershire. It may be an intermittent deposit, for several sections showing the junction of the Middle and Upper Lias have been carefully investigated, for example, those at Alderton,[||] Langley ("Gretton"), and Churchdown Hills,[¶] and King Street, Stroud,[**] but in all the lowest beds seen have been the *Leptæna*-Shales, which are followed by the "Fish-

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[*] L. Richardson, *Proc. Cotteswold Nat. F. C.*, vol. xvi, pt. 1 (1907), p. 27.

[†] S. S. Buckman, *Quart. Journ. Geol. Soc.*, vol. lix (1903), pp. 445-464.

[‡] S. S. Buckman, *Quart. Journ. Geol. Soc.*, vol. xlv (1889), pp. 444-445.

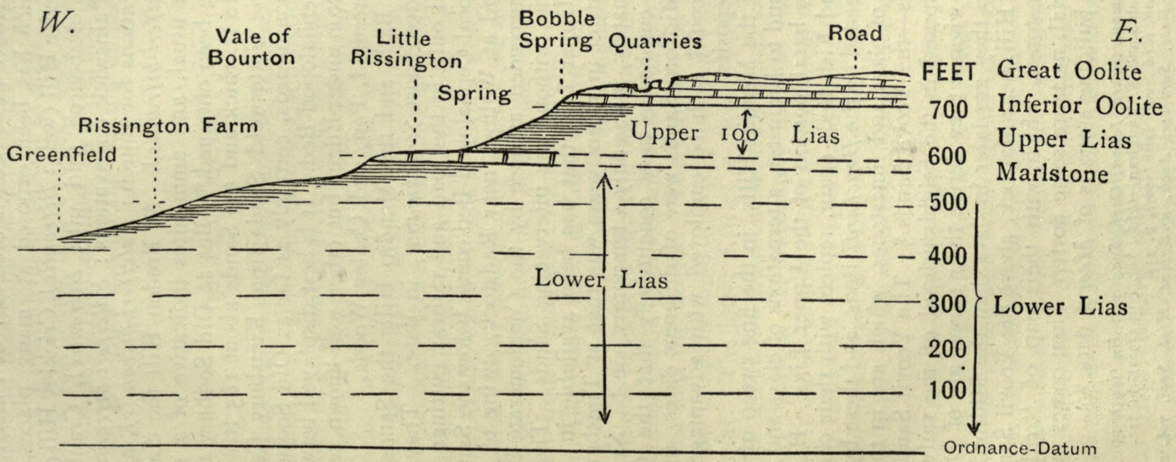
[§] B. Thompson, *Rep. Brit. Assoc.*, for 1891, p. 350.

[||] Wright, *Proc. Cotteswold Nat. F. C.*, vol. iii, p. 153; F. Smithe and W. C. Lucy, *ibid.*, vol. vii, pt. 2 (for 1879-80), p. 149.

[*] F. Smithe, *ibid.*, vol. iii, p. 40; and vol. vi, p. 374.

[¶] C. Upton, *ibid.*, vol. xv., pt. 3 (1906), p. 201.

FIG. 57.—SECTION ACROSS THE ESCARPMENT AT LITTLE RISSINGTON.—*L. Richardson.*



SCALE :—Vertical, 1 inch=400 feet ; Horizontal, 3 inches=1 mile.

Beds "—deposits which have been tentatively dated as "pre-*Falciferi*." Above these beds is blue clay of *Falciferi-bifrontis* hemeræ, which has been exposed at many places, amongst others, at Cleeve Hill (well : *Bifrontis)*, Crickley Hill *(Falciferi-bifrontis)*, Colesbourne (old pit : *Bifrontis)*, Cranham (pit : *Bifrontis)*, Painswick (excavations : *Falciferi-bifrontis)*, Nailsworth (excavations for church : *Falciferi-bifrontis)*, and Stinchcombe *(Falciferi-bifrontis)*. At Bredon Hill the clay is much thicker than usual, and ammonites indicative of a number of hemeræ have been obtained.[*] But at Old Sodbury the clay is only about 10 ft. thick and the Sands about 185 ft.[†]

Above the Cotteswold Sands from Kimsbury Castle, near Painswick, southwards, certainly as far as Old Sodbury, is the celebrated Cephalopod-Bed. It is best displayed between Dursley and Wotton-under-Edge, but other well-known sections are those at Haresfield, Pen, and Coaley Woods.

Between Bath and the Mendip Hills the Sands are post-*Striatuli*, indeed post-*Struckmanni*, in date. They are now well exposed only in the road and railway cuttings near Midford. The local Cephalopod-Bed comes below the Sands instead of above, and at Wellow, near Radstock, owing to uplift and erosion, is succeeded at once by the Conglomerate-Bed of the Inferior Oolite without any intervening Sands. The best section of the Upper Lias that has been available in the Bath-Doulting district in recent years was that at Timsbury Sleight, but, unfortunately, it was only a temporary one.[‡] Nevertheless, it served to emphasise most conclusively that the Cotteswold Sands and Midford Sands were of different dates, and that the two names could each be employed with advantage for their respective deposits.

South of the Mendip Hills, in the fine sweep of hills from Doulting round to Ilminster, alternations of clays and limestones make up the basal portion of the Upper Lias. Here are the *Leptæna*- and Fish-Beds again, replete with their characteristic fossils, succeeded by the *Bouchardi*-Beds, and these by more thin alternations of clays and limestones, which are in turn capped by the Sands—the Yeovil Sands.[§] The Yeovil Sands, so magnificently exposed in the neighbourhood of the railway-station of the town whence they derive their name, are of *Dumortieriæ* hemera. So they are later in date than the Midford Sands.

At Ham Hill, near Martock, above the Yeovil Sands are the building-freestones, which, with their cap of "riddings," or waste material, measure some 80 ft. Then comes more yellow sand. The building stone is of *Moorei* date.[||]

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[*] S. S. Buckman, *Quart. Journ. Geol. Soc.*, vol. lix (1903), pp. 445-464.

[†] S. H. Reynolds and A. Vaughan, *ibid.*, vol. lviii (1902), p. 732.

[‡] L. Richardson, *ibid.*, vol. lxiii (1907), p. 413.

[§] C. Moore, *Proc. Somerset Arch. and Nat. Hist. Soc.*, vol. xiii (1867), pp. 119 *et seqq.*

[||] *Proc. Geol. Assoc.*, vol. ii, p. 247; and "Record of Excursions," p. 343.

At White Lackington Park, near Ilminster, the bed of *Dispansi* hemera, that is of the date of the Midford Sands, or at any rate of a considerable portion of them, consists of an arenaceous marl-bed two inches thick, and a yellowish-grey soft stone 9 ins. thick; while bluish clay with occasional nodules is placed by Mr. Buckman on the horizon of the *Striatulum*-Bed of the Cotteswolds.*

INFERIOR OOLITE.

In Gloucestershire and Somerset the Inferior Oolite rocks form the mural scarp at the top of a long and frequently deeply-indented line of hills that stretches from near Stratford-on-Avon to near Ilminster, and overlooks the low ground where the Liassic rocks prevail. Outliers, such as Glastonbury Tor, Brent Knoll, Dundry Hill, Robins' Wood Hill, and Bredon Hill, rising conspicuously above the vale-land and situated well in advance of the main escarpment, are the relics of a time when the Inferior Oolite extended much farther west. From their summits and the many commanding spurs of the main hill-mass, views may be obtained over one of the most varied districts in this country from a geologist's point of view.

The Inferior Oolite rocks of this tract are better known than those of almost any other. Certainly more minute subdivisions and correlations have been effected than anywhere else.

The Inferior Oolite of this country presents two main types—the estuarine and the marine. The former type predominates in the Yorkshire-Stonesfield district; the latter in the Stonesfield-Bridport. The latter district is divisible into two portions on geological grounds—the Stonesfield-Doulting, and the Doulting-Bridport districts. It fortunately happens that this latter subdivision is not unsuitable from a geographical standpoint, for the Mendip Hills very nearly form the dividing line.

Stonesfield-Doulting district.—This district includes the Cotteswold Hills and the nameless upland tract between Bath and Doulting.

The most easily recognised bed in this district is the Upper *Trigonia*-Grit. It extends from a line a short distance west of the Moreton Valley right away to Mells, near Frome; reappearing on the south side of the Mendip Hills in the railway-cutting at Doulting. In the Bath-Doulting district and at the eastern end of Dundry Hill it is conglomeratic, but at the western end and in the Cotteswold Hills it is non-conglomeratic.

Where the greatest development of the series obtains in the Cotteswold Hills, twenty subdivisions of the infra-Upper *Trigonia*-Grit Inferior-Oolite rocks have been made, and are the result of deposit during ten hemeræ. Even then deposits of *Blagdeni* and *Niortensis* hemeræ are absent.

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* *Quart. Journ. Geol. Soc.*, vol. xlv (1889), p. 450.

Detailed palæontological work in the field and study has made it possible to indicate with considerable precision the geographical distribution of the various subdivisions, and it has been found that the disappearance of the Ragstone-Beds between the Freestones and the Upper *Trigonia*-Grit is satisfactorily explained on the hypothesis that shortly before the hemera *Garantianæ* crust-pressures produced flexuring of the deposited beds, and anticlines and synclines were formed, the rocks on the anticlines were removed according to their amount of elevation and those in the synclines preserved according to the amount of their depression, and then the Upper *Trigonia*-Grit was laid down non-sequentially upon a waterworn and bored surface of the underlying beds.

The two main anticlines in the district under consideration were along the line of the Moreton Valley and the Mendip Hills and intersected at right angles somewhere in the neighbourhood of the Marlborough Downs. The principal synclinal axis radiated out by way of Cleeve Hill. An important anticline was at Birdlip; a syncline in the neighbourhood of Painswick; but thence southwards, right away to the Mendips, was the one long limb of a gentle anticline, with, maybe, one slight anticlinal roll. These anticlinal and synclinal axes are old lines of weakness, and were old even in Bajocian times. Along them repeated movements of varying intensity have taken place, and have to no small extent governed the conditions of deposition of the *Bradfordensis* and pre-*Bradfordensis* Inferior-Oolite beds.

The several subdivisions may be considered in ascending order.

The *Opaliniforme*-Bed is best developed in the neighbourhood of Dursley, and is succeeded by the *Scissum*-Beds, which have a far greater geographical distribution. They extend from the North Cotteswolds certainly as far south as Old Sodbury, and there are sections of them near Wood Farm (near Guiting Power); Puckham, on the Cleeve-Hill plateau; Birdlip; Cooper's Hill; Frocester Hill; Coaley Wood; and Wotton-under-Edge. The succeeding Lower Limestone is best developed in the neighbourhood of Stroud,* where it has been much quarried, but—except for *Pecten (Amusium) personatus*, which is not uncommon near the top or at the base of the Pea-Grit, and characterises beds of the same date in Germany—it is far from fossiliferous. At Selsley Hill its beds are conglomeratic, and are known locally as the "dapple-beds." The Pea-Grit is excellently developed between Cleeve Hill and Stroud, its detached pisolite spherules—which, on account of their resemblance to crushed peas, obtained for the subdivision its name—strewing the quarry slopes at Cleeve, Crickley, and Birdlip Hills. While some of the pisolite spherules are of mechanical origin, the majority have been formed by the growth of a tubular organism, probably algal, around a nucleus.* The top-beds of the Pea-Grit are rubbly, and it is probably this portion alone that is found at Selsley Hill and is represented by the thin bed parting the Lower Limestone from the Lower Freestone at Frocester Hill and Coaley Wood. South of Coaley Wood, in the Dursley and Wotton-under-Edge districts, the freestone beds are best spoken of as simply the "Freestone Series," without any attempt at differentiation. In the North Cotteswolds the pisolite gives place to a warm-brown building-stone known in building-circles as the "Guiting Stone" on account of its being largely quarried near the village of Temple Guiting. There are large quarries in it at Bourton-on-the-Hill; but at Ebrington Hill it has become very sandy, and the Lower Limestone is the freestone that has been worked so extensively there in the past.† At the top of the Pea-Grit, where it is well developed, is a coral bed—the Fourth Coral-Bed—very rich in micro-organisms, but of restricted geographical extent, being conspicuously developed only in the tract between Crickley Hill and The Frith.

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* E. Witchell, *Proc. Cotteswold Nat. F.C.*, vol. viii, pt. 1 (for 1881-82), pp. 35-49: *Quart Journ. Geol. Soc.*, vol. xlii (1886), pp. 264-271.

The Lower Freestone, which is the next subdivision, is a most important mass of rock, for it furnishes the well-known Cheltenham building-stone that is quarried at Leckhampton Hill, where it is 77 ft. 9 ins. thick.‡ The Oolite Marl, which succeeds (Plate XI), is essentially a Cotteswoldian deposit; is rocky in places, clayey in others; is replete with *Terebratula fimbria,* and in the neighbourhood of Stroud with *Nerinææ;* and includes the Third Coral-Bed of the Cotteswold Hills. In the neighbourhood of Cheltenham and in the North Cotteswolds this subdivision is usually well marked off from the Upper Freestone; but at Birdlip it is doubtfully discernible; at The Frith Quarry it is difficult to separate from the Upper Freestone;§ and at Selsley Hill is somewhat masked by the interstratification of impersistent limestone-beds, but is succeeded by freestones referable to the Upper Freestone. South of Selsley Hill, however, it does not extend. The Upper Freestone, as will have been gathered from the foregoing remarks, is usually worthy of that name, but occasionally—as at The Frith—is not. There, near the top, is a line along which *Rhynchonella tatei* is abundant. At Wagborough Bush, near Bourton-on-the-Water, this horizon rests directly upon the Lower Freestone without any intervening Oolite Marl,‖ although the Oolite Marl is well developed in places in the North Cotteswolds—for example, at the Campden Hill Quarry.* The indefiniteness of the Oolite Marl on the Birdlip anticlinal axis, combined with its absence from the Wagborough Bush section near the Moreton anticline, suggests that in *Bradfordensis* times there were crust-movements, resulting in producing a certain restriction of the area over which the deposit of the hemera *Bradfordensis* was laid down.

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* E. B. Wethered, *Quart. Journ. Geol. Soc.*, vol. xlvi (1890), pp. 270-281; *ibid.*, vol. xlvii (1891), pp. 550-569.

† L. Richardson, *Proc. Cotteswold Nat. F.C.*, vol. xvi, part 2 (1908), p. 129.

‡ L. Richardson, *Proc. Cotteswold Nat. F.C.*, vol. xv, pt. 3 (1906), p. 189.

§ S. S. Buckman, *Quart. Journ. Geol. Soc.*, vol. li (1895), p. 399.

‖ L. Richardson, *Proc. Geol. Assoc.*, vol. xviii (1904), p. 404.

The Upper Freestone completes the Freestone Division of the Inferior-Oolite Series. Above come the Ragstone-Beds, which have been divided into two parts—the "Intervening-Beds," which come between the Upper Freestone and Upper *Trigonia*-Grit; and the "Top-Beds," which include the remainder (*plus* the Upper *Trigonia*-Grit).

Crust-pressures must have produced flexuring again in late *Bradfordensis* hemera, for the deposits of *Concavi* hemera which succeed, whilst they are well-developed in the North Cotteswolds and have been divided into five parts, namely, the Blockley Clay, Harford Sands, Lower Snowshill Clay, Tilestone, and Upper Snowshill Clay,† on Cleeve Hill are represented only by the Harford Sands and Snowshill Clay, and on Charlton Common by a portion of that clay only, which is absent from the neighbouring Leckhampton Hill.

At the bottom of the next deposit—the Lower *Trigonia*-Grit—where it is well developed, is the Second Coral-Bed. The Lower *Trigonia*-Grit has the widest distribution of the Intervening-Beds, extending from the North Cotteswolds to just beyond the Cuckoo-Pen Quarry, being present in the Painswick synclinal area, and reaching across to Rodborough Hill on the south side of the Stroud Valley. The succeeding *Buckmani*-Grit, with its characteristic yellow sand-deposit and associated clay-bed, has a less extent than the lower *Trigonia*-Grit, from which it may be separated in not being finely ironshot. It is well exposed at Sudeley Hill, the "Roadstone Hole" (Cleeve Hill), Leckhampton Hill, Tuffley's and Dunley's Quarries, and The Frith; while a thin representative may be studied at The Fort Quarry on Rodborough Hill.‡ The Gryphite-Grit is typically developed at Leckhampton Hill, but is not always so full of gryphæas, and when such is the case is none too easy to separate from the *Buckmani*-Grit. The Notgrove Freestone is an important bed in the North Cotteswolds, measuring anything up to 25 ft. It is present on Cleeve, at Charlton Common, and Leckhampton Hill, where its top-bed is markedly bored and oyster strewn. Between the last locality and the neighbourhood of The Frith it is absent, and in the latter part is only feebly developed.

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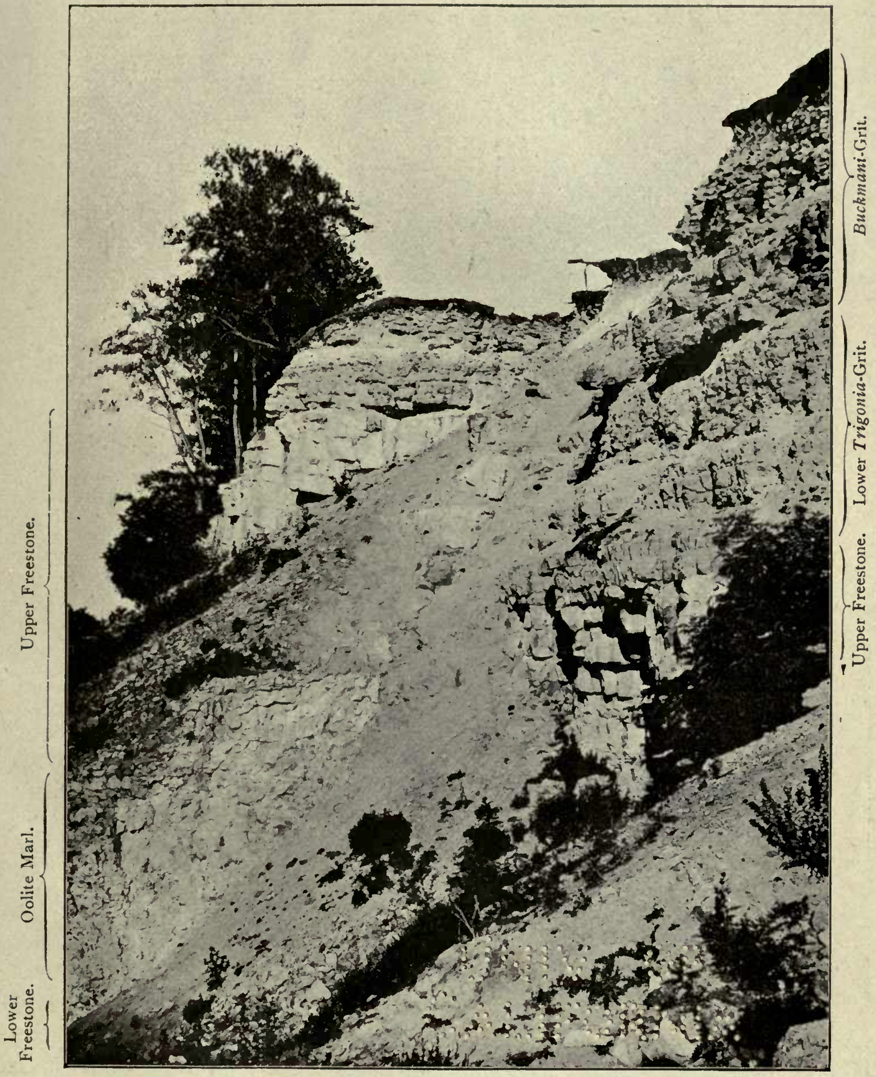
* *Proc. Geol. Assoc.*, vol. xviii (1904), pp. 394-395.

† S. S. Buckman, *Quart. Journ. Geol. Soc.*, vol. lvii (1901), p. 130.

‡ *Proc. Geol. Assoc.*, vol x (1887), pp. 160-161.



[*Photo by J. W. Gray.*

VIEW OF A FAULT AT LECKHAMPTON HILL, NEAR CHELTENHAM.

(Reproduced by permission of the Cotteswold Naturalists' Field Club.)

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The beds from the Lower *Trigonia*-Grit up to the Notgrove Freestone have a successively decreasing geographical extent. The *Witchellia*-Grit outside the Cleeve Hill plateau is found only in a small tract of country around Cold Comfort, where it included the once celebrated *Perna*-Bed,* which now appears to be quite worked out; and the *Phillipsiana*- and *Bourguetia*-Beds on the Cleeve-Hill plateau alone. † The *Phillipsiana*- and *Bourguetia*-Beds are of *Sauzei* hemera. The nearest other place where deposits of this date are found is at Dundry Hill; but as Dundry Hill was connected with the "Dorset area" and not with the Cotteswold, the fauna of the two localities differs considerably. Therefore the Rolling-Bank Quarry section on Cleeve Hill is of exceptional interest in that it affords a collecting ground almost unique. Here the top-bed of the *Phillipsiana*-Beds is conspicuously bored, and is succeeded by the Upper *Trigonia*-Grit.

The Upper *Trigonia*-Grit, as has been pointed out, was laid down during a period of general subsidence, following one of flexuring. It is doubtful if it extended across the line of the Moreton Valley. After its formation there were renewed, but feebler, crust-movements. In places in the Bath-Doulting district some reconstruction of its body may have taken place, and, if ever it had been laid down across the Moreton Valley, it was at this time denuded. Anyhow, an area of sedimentation was formed with Dundry Hill and Timsbury Sleight as localities in it, and the Dundry Freestone—a valuable building-stone at least 27 ft. thick in the quarry near Dundry Church—was laid down.‡ During its formation the Upper *Trigonia*-Grit, where not covered by sediment, was eroded, bored, and oyster strewn; and then, while the whole area was sinking, the corals of the Upper Coral-Bed flourished, and must have been the most conspicuous inhabitants of a sea teeming with micro-organisms.

This Upper Coral-Bed constituted a most valuable datum-level for correlating the Top-Beds of the Inferior Oolite of the Stonesfield-Doulting district, not that it is persistent, for it is precisely the reverse, but its micro-fauna—especially *Spiriferina oolitica*—and species of *Isastræa* are so very distinctive, not to mention certain echinoids, brachiopods, and lamellibranchs. The Upper Coral-Bed has been located in the Rolling-Bank Quarry, on Cleeve Hill, is well developed at Worgan's Quarry in the Slad Valley, near Stroud;§ the Mount-Vernon Quarry, Rodborough Hill; || Nibley Knoll; Midford; Timsbury Sleight;

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* T. Wright, *Quart. Journ. Geol. Soc.*, vol xvi (1860), p. 42.

† S. S. Buckman, *Quart. Journ. Geol. Soc.*, vol. liii (1897), p. 613.

‡ S. S. Buckman and E. Wilson, *ibid.*, vol. lii (1896), p. 679; *Proc. Bristol Nat. Soc.*, n.s., vol. viii, pt. 2 (for 1896-97), p. 194; *Proc. Geol. Assoc.*, vol. xiii, (1893), p. 128.

§ L. Richardson, *Proc. Geol. Assoc.*, vol. xx (1908), p. 522.

|| L. Richardson, *Proc. Cotteswold Nat. F.C.*, vol. xvi, pt. 1 (1907), pp. 73-74: E. Witchell, "Geology of Stroud" (1882), p. 55.

and Dundry Hill; while traces have been observed elsewhere.

In the Bath-Doulting district, above the Upper Coral-Bed—which is definitely of *Truellei* hemera—comes (in ascending order) the Doulting Stone, *Anabacia*-Limestones, and Rubbly Beds.* The Doulting Stone includes the celebrated Doulting Freestone, which is also of *Truellei* hemera, although slightly later, of course, than the Upper Coral-Bed. At Doulting the Freestone is still largely worked, and the subdivision to which it belongs extends right across the well-planed, bored, and oyster-covered surface of the Carboniferous Limestone in the picturesque neighbourhoods of Holwell, Nunney, and Vallis Vale, and northwards into the South Cotteswolds. The *Anabacia* Limestones, characterised by the little coral *Anabacia complanata*, are co-extensive with the Doulting Stone, and also extend into the South Cotteswolds; but the Rubbly Beds are not so persistently developed: they are best seen at the Doulting Bridge and Farmcombe Quarries; and while they are very thin in the neighbourhood of Radstock, have thickened out at Tog Hill in the South Cotteswolds. Indeed, at the southern end of the South Cotteswolds the Inferior-Oolite beds are very similar to their equivalents south of the Avon Valley. As the beds are traced northwards, however, a change sets in. First the Doulting Stone becomes more fossiliferous, as is seen at the Horton Rectory Quarry in the South Cotteswolds,† and constitutes from thence northwards the local *Clypeus*-Grit. The *Anabacia*-Limestones, under the name of White Oolite, retain more or less their distinctive appearance as far north as Nailsworth, and the Rubbly Beds are seen here and there above them. But north of Stroud, the Doulting Stone or local *Clypeus*-Grit, the *Anabacia*-Limestones or White Oolite, and the Rubbly Beds pass as a whole into the *Clypeus*-Grit of the Cheltenham district, and were once continuous across the Moreton Valley.‡

During the latter part of the nineteenth century the Association has studied the Inferior Oolite of the neighbourhoods of Cheltenham and Stroud on several occasions; and in the present century, in the years 1904 and 1908, has visited the North, Mid, and the northern portion of the South Cotteswolds, with a view to studying the subdivisions of the Inferior Oolite and their distribution, and the hypothesis which attributes their appearance and disappearance to the effects of flexurings and erosions.

On the south side of the Mendip Hills the Inferior Oolite caps the hills that sweep with crescentic trend from Doulting, past Castle Cary, Bruton, Yeovil, and South Petherton to Ilminster, and pass into Dorset to the south of Crewkerne.

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* L. Richardson, *Quart. Journ. Geol. Soc.*, vol. lxiii (1907), p. 386.

† W. H. Hudleston, "Gasteropoda of the Inferior Oolite," *Pal. Soc.* (1887-8), pp. 56-63.

‡ *Quart. Journ. Geol. Soc.*, vol. xlix (1893), pp. 479-522.

In the neighbourhood of Sherborne the sum of the maxima of the various zones may be, according to Mr. S. S. Buckman, as much as 130 ft. The deposits of *Garantianæ*, *Truellei*, *Zigzag*, and *Fuscæ* hemeræ claim a big share of this, for the well-known Sherborne building-stone, of *Garantianæ* hemera, is at least 20 ft. thick, and the "Limestone Beds" of the neighbourhood of Bradford Abbas measure about 32 ft. The latter are of *Fuscæ-zigzag* hemeræ, from which it will be remarked that deposits of these dates are of variable lithic structure, being sometimes Fuller's Earth and at others Inferior Oolite.*

As in the Cotteswold Hills and Bath-Doulting district, so in this the deposit of *Garantianæ* hemera spreads over a frequently eroded surface of the underlying beds, thereby separating, more or less distinctly, the "Top-Beds" from the underlying strata. These lower beds are of *Scissi-niortensis* hemeræ inclusive, but are subject to considerable variation both as regards geographical distribution and thickness. As the result of his work, Mr. Buckman was able to state that the deposits of *Murchisonæ* hemera overstep from east to west the *Scissum*-Beds, thickening at the same time. The beds of *Bradfordensis* date also thicken from east to west, but the succeeding deposits of *Discitæ* hemera are more uniform as regards distribution and thickness. Then certain uplifts occurred, and the area of maximum sedimentation was shifted to the east, the *Witchellia*-Beds being found only well developed in the latter region. Subsidence followed and the *Sauzei*-Beds spread westwards, overlapping the *Witchellia*-Beds, and coming in contact with those of *Discitæ* date. Again there was uplift in the west and a shifting of the area of sedimentation to the east, the deposits of *Blagdeni* and *Niortensis* hemeræ being found in the latter direction. The reverse conditions followed, and the *Garantiana*-Beds are found thickest in the west. The deposits of *Truellei*, *Zigzag* and *Fuscæ* date, usually limestones, follow, and complete the series to which the term Inferior Oolite is applicable in this district.

In the Cotteswold Hills and Bath-Doulting district the sub-Upper *Trigonia*-Grit Inferior Oolite rocks were thrown into a series of anticlinal and synclinal flexures in pre-*Garantianæ* times. The same was the case in this region south of the Mendip Hills. While some of the variations in thickness of the various strata may be the outcome of slightly antecedent crust-flexurings restricting the areas of sedimentation, others are no doubt due to the way in which they were flexured and denuded during the Bajocian Denudation. Mr. Buckman† has approximately indicated the geographical distribution of the beds upon which the deposit of *Garantianæ* hemera rests.

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* *Proc. Dorset Nat. Hist. Club*, vol. xiv (1893), pp. 37-43.

† *Quart. Journ. Geol. Soc.*, vol. lvii (1901), p. 130.

No work has been done in the neighbourhoods of Bruton, Sherborne, or Yeovil since Mr. Buckman's essay and the Geological Survey Memoirs were published, so the reader is referred to them for details of the various sections.

GREAT OOLITE SERIES.

The term "Great Oolite Series" is here used to embrace the whole of the deposit intervening between the limestones of the Inferior Oolite and the Kellaways Clay at the base of the Oxfordian. This leaves the term "Great Oolite" free wherewith to distinguish the important mass of freestone and associated ragstones that make their appearance at a distance some six miles south of Bath, and then persist throughout the Cotteswold Hills; while the term "Bathonian" includes all the deposits intervening between the Oxfordian and the deposit of *Garantianæ* hemera, and inclusive of the latter.

Above the Inferior Oolite the next easily-located horizon is the Cornbrash, which, like the topmost portion of most great stratigraphical divisions, is of wide extent, stretching from the shores of the English Channel, near Weymouth,* to the coast of Yorkshire at Gristhorpe and Cayton Bays. It is evidently the product of comparatively slow deposition in tranquil waters, free from the numerous currents that originated the false-bedding of some of the subjacent limestones, and varies in thickness between 10 and 35 ft. Usually pale brown, sometimes sandy, richly fossiliferous rubbly limestones predominate, which are well suited for the growing of wheat; but occasionally, as near Closeworth (on the borders of Dorset and Somerset), clay-beds make their appearance amid the rubbly limestones.

In the district under consideration the Cornbrash is well marked off from the deposits above and below. Owing to the fact that it is underlain by the Forest Marble clays it is an important water-containing bed, and its outcrop is therefore either marked by a number of important villages or they are situated at a short distance to the east of it on the Oxfordian deposits.

As the Cornbrash presents so similar characters over the area under review it will be sufficient to mention a few of the localities where it may be studied with the most advantage.

In Somerset there are quarries exhibiting rubbly limestones rich in fossils, at Weston, between Sutton Bingham and Close-

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* The section referred to by Mr. H. B. Woodward, *Mem. Geol. Surv.*, "The Jurassic Rocks of Britain," vol. iv (1894), p. 435, is now mostly hidden, but on the high ground on the opposite side of the lake is a quarry where the usual fossils can be obtained.

APPROXIMATE CORRELATION-TABLE FOR THE AALENIAN (*pars*), BAJOCIAN AND BATHONIAN.

		DORSET COAST.	SOMERSET, MID.	COTTESWOLD HILLS.			NORTHAMPTONSHIRE —LINCOLNSHIRE.	YORKSHIRE COAST.
BATHONIAN.	Cornbrash.	←			Cornbrash.			→
	Forest Marble.	Clay. Limestone. Clay.	Clay. Limestone. Clay.		Clay. Limestone. Bradford Clay.		Great Oolite or Blisworth Clay.	Upper Estuarine.
	Fuller's Earth.	Fuller's Earth.	Upper Fuller's Earth Clay.	Great Oolite. Upper.	Upper Rags.	Kemble Beds. White Oolite.	Great Oolite.	
			Fuller's Earth Rock.	Great Oolite. Lower.	Freestones.	Minchinhampton Stone.		
					Lower Rags.	Stonesfield Slate.		
			Lower Fuller's Earth Clay.			Fuller's Earth, 1 ft. thick, at Great Rissington.	Upper Estuarine.	
AALENIAN-BAJOCIAN.	Inferior Oolite.	Top-Beds of the Inferior Oolite down to the deposit of *Garantianæ* hemera.						(Moor Grit.) Scarborough Limestone (*Blagdeni*).
		Deposits in their maximum development dating from *Blagdeni* to *Scissi* inclusive.		(*Niortensis-Blagdeni* deposits absent.)				Middle Estuarine,
				Deposits of *Sauzei-Sonniniæ* hemeræ, *Buckmani-* and Lower *Trigonia-* Grits.		. . . .	Lincolnshire Limestone.	Millepore Limestone, or Whitwell Oolite (*Discitæ*).
				Concavum- and *Bradfordensis*-Beds. Lower Freestone, Pea-Grit, Lower Limestone, and *Scissum*-Beds.			Lower Estuarine. Northampton Sand.	Lower Estuarine. The Dogger.

worth (some three miles south of Yeovil), and by the main road east of the latter village, where there are some intervening clay beds. The outcrop of the Cornbrash then recedes into Dorset and does not re-enter Somerset until near Henstridge (near Milborne Port), between which place and Templecombe—and particularly around the latter town and farther north at Wincanton—are numerous sections in road and railway cuttings and quarries. From Wincanton northwards the outcrop is not marked by any quarries of note, although at Upton Noble some hard associated limestones have been worked for building purposes. In the neighbourhood of Frome there are shallow quarries west of Rodden; north-west of Berkley; and again at Langham Mill, north of Road, where fossils are particularly abundant; while it was from near Chatley, between Norton St. Philip and Woolverton (near Road), that Sowerby obtained a number of specimens, which he figured and described, including *Pecten vagans.* The boundary of the district under review does not take in any more Cornbrash land until the neighbourhood of Malmesbury is reached, and then it is but a small piece. The mention of Malmesbury, however, affords an excuse for referring to a most fossiliferous section within easy access of the town. Crossing the Avon on the west side of the town by the footbridge near the mills, and following the path along the riverside as far as the Foxley road, a quarry will soon attract attention. Fossils abound, and are very well preserved. They include *Acrosalenia spinosa*, *A. wiltoni*, *Echinobrissus clunicularis*, *Holectypus depressus*, *Natica* spp., *Ornithella* spp., *Isocardia minima*, *Pecten vagans*, *Pseudomonotis echinata*, *Limea duplicata*, *Lithophagus inclusus*, *Ostrea costata*, *Ostrea lotharingica*, etc. Just within Wiltshire the Cornbrash is well exposed in the sides of the lane that passes from Great Barn under the Tetbury line (G.W.R.), scarce ten minutes' walk from Kemble Junction. Here forms of *Ornithella obovata* are the predominant fossils, but *Terebratula intermedia* is not infrequent. It is said that the former species prevails in the upper portion of the Cornbrash, and the latter in the lower. On the borders of Gloucestershire and Wiltshire, at the cross roads half-a-mile north-north-west of Sharncott, is a shallow quarry, where *Ornithella siddingtonensis* is abundant; but after that there is no section of note until Ampney Crucis is reached, where 5 ft. of Cornbrash is seen, separated by 5 ft. of clay from some 20 ft. of Forest Marble. Between Fairford and the borders of Oxfordshire the Cornbrash has a considerable superficial extent, but the few quarries that there are, are only shallow, and present no feature worthy of special mention.

The next subdivision of the Great-Oolite Series, which everywhere underlies the Cornbrash in its course through Somerset and Gloucestershire, is the Forest Marble. Typically, this subdivision is divisible into three parts: a medium limestone series with sub- and super-jacent clays—the inferior clay-bed being particularly fossiliferous, and in places known as the Bradford Clay. The subdivision, however, is subject to some variation, for in places limestones predominate to the detriment of the clays, and while in the south-west it is obviously a shallow-water deposit of marine origin, in Northamptonshire, Buckinghamshire, and farther north the whole is represented by clays—the Blisworth or Great-Oolite Clays.

On the Dorset Coast the total thickness of the series is about 80 ft.; that is what it measures at West Cliff, Bridport.

The equivalent to the Bradford Clay is admirably exposed on the shore close to Fleet House, near Langton Herring, to the west of Weymouth. Here fossils are extremely abundant, especially *Rhynchonella boueti*, on which account the term "*Rhynchonella*-Bed" has been employed to denote the deposit.* Although, of course, this bed may subsequently be found exposed somewhere between Bothenhampton and Bradford-on-Avon, it has not been as yet; but at the latter locality it is magnificently developed, and is known as the "Bradford Clay." In the intervening district it is the limestone portion that is most in evidence, but the total thickness of the subdivision probably remains about the same—about 130 ft. Frome is built upon the Forest Marble, and between there and Freshford the rock spreads out over a considerable tract of country. The Bradford Clay is best exposed just within Wiltshire at Bradford-on-Avon, where it is well seen above the Great Oolite at the Woodside Quarry to the south of the town.†

Mr. H. B. Woodward has written:‡ "It seems evident that locally there was some pause in deposition between the Great Oolite and Bradford Clay, for the crinoids or stone-lilies (for which Bradford-on-Avon is famous) must have flourished in clear water on the floor of the Great Oolite before the muddy sediments of the Bradford Clay were laid down. Moreover, it has been noticed that some of the crinoids have been covered with serpulæ, and afterwards encrusted with polyzoa." This is the case at the Fleet House section near Langton Herring; there the majority of the specimens of *Pecten vagans*, *Rhynchonella boueti*, and *Terebratula langtonensis*, are covered with serpulæ, polyzoa, and the foraminifer *Webbina*.

Although the Bradford Clay has a somewhat impersistent development, it is present in the old quarries on Farley and Bathampton Downs, where I have collected *Apiocrinus parkinsoni*, *Dictyothyris coarctata*, *Eudesia cardium*, *Ornithella digona*, etc.

In the country around Tetbury, Cirencester, Chedworth, and

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* *Mem. Geol. Surv.*, "The Jurassic Rocks of Britain," vol. iv (1894), p. 341, and see *post* pp. 391 and 395.

† *Proc. Geol. Assoc.*, vol. xiii (1893), pp. 132-133; and see *ante*, p. 296.

‡ *Op. cit.*, vol. iv, p. 353.

Northleach the Forest Marble has a considerable geographical extent. Traces of Bradford Clay, attaining a maximum thickness of 8 ft., and yielding many of the characteristic fossils, have been observed in the railway-cuttings at Kemble; in the cutting for the road under the railway near the site of the old Tetbury-Road Station; near the Mount, Trewsbury Castle; at Ewen; at Smerrill Quarry, north-east of Kemble; Jarvis's Quarry; at Tiltup's End, near Nailsworth (where it is a thin bed full of specimens of *Rhynchonella obsoleta*); and near the sixth milestone on the Minchinhampton Road, half-a-mile north of Avening; while the stone-beds are worked at many places, and at Chavenage have yielded "tiles" suitable for roofing purposes. By the canal-side at Blue House, not far from Furzen Leaze, about 8 ft. of Bradford Clay is exposed, being dug for puddling the canal.

At places in the neighbourhood of Fairford corals have been found in considerable numbers in a position about the top of the Great Oolite, and in sufficient quantities to have gained the name of the "Fairford Coral-Bed." Now, however, they are seldom found and most of the quarries in that neighbourhood are abandoned, including those at Poulton. The best section is that at Ampney Crucis, to which reference has been already made.

On the Dorset coast, between the equivalent to the Bradford Clay and the Inferior-Oolite limestones, is—as far as can be seen—nothing but clay, which goes under the name of Fuller's Earth. It contains few fossils, and must measure something like 150 ft. Leaving the coast and proceeding inland, however, a bed of impure limestone soon makes its appearance in this great clay series, and between Thornford and Sherborne gives rise to a noticeable ridge, which is scarred by a number of quarries. Fossils abound, and the various road and railway cuttings and quarries afford ample opportunities for collecting. This Fuller's Earth Rock, as the impure limestone is called, produces a threefold sub-division of the Fuller's Earth. At Scale Hill, near Evercreech, according to Sir Henry de la Beche, their respective thicknesses, in ascending order, are 21, 25, and 133 ft. To the north, the bottom portion of the Fuller's Earth, the *Knorri*-Clays, is excellently exposed in the neighbourhood of Doulting, and is occasionally to be seen filling in pockets of fissures in the Top-Beds of the Inferior Oolite in the Radstock district. In the Cotteswold Hills sections are few and far between.

The Fuller's Earth Rock is traceable from the Sherborne district as far north as Dyrham in the South Cotteswolds, near which village is an excellent exposure; but, except in the southern portion of the intervening district, it is rarely seen, although there are sections at Alham Lane. a quarter of a mile east of Chesterblade (between Evercreech and Doulting), and a less convincing one at Midford. Here and there are the usual kinds of sections of the Upper Fuller's Earth, and in the neighbourhood of Midford, near Bath, a particular bed from 4 ft. to 7 ft. thick furnishes the economic Fuller's Earth, and is still worked, but at only one place—between the Cross Keys Inn and Midford Castle.* The deposit has yielded a large number of Ostracoda.†

Between Dyrham and Chedworth the sections now open do not permit of one seeing if the threefold division of the Fuller's Earth still persists. All that can be said is that limestone bands are present, practically made up of the valves of *Ostrea acuminata*. Very fair sections of the Fuller's Earth, however, have been opened up in certain of the railway cuttings in the neighbourhoods of Chedworth‡ and Hampen, near Andoversford.§ In the former neighbourhood the Fuller's Earth is about 50 ft. thick, and in the latter from 25 ft. to 30 ft.‖ Clay, with two *Ostrea-acuminata*-Limestones, 1 ft. thick, is all that remains of the Fuller's Earth in the neighbourhood of Rissingtons, near Bourton-on-the-Water.

About six miles south of Bath, where the Fuller's Earth rock begins to be less conspicuous, there appears somewhat suddenly —apparently between the Upper Fuller's Earth and Bradford Clays—a variable series of oolitic freestones, shelly limestones, compact white limestones and marls, and fissile, sandy, and oolitic limestones. These constitute the Great Oolite proper, and extend from the neighbourhood of Bath to the confines of the district under review, near Chipping Norton. Throughout this region the Great Oolite is divisible into two portions—an Upper and a Lower. Each has been sub-divided, and usually into two parts (see the table on page 351).

In the neighbourhood of Bath the freestones are of considerable importance, and in the past have been very actively worked, as the numerous quarries on Farley, Bathampton, Combe¶ and Odd Downs attest. Away from the more populous centres, in the South Cotteswolds, the beds are less frequently opened up; but at Minchinhampton,** near Stroud, there are large quarries again, which have long furnished an excellent building-stone, and numbers of beautifully-preserved fossils, many of which have been figured and described by Morris and Lycett.†† Here the basement-beds first present those fissile properties that have made them so useful for splitting for "slates." In the Cotteswold Hills they are now actively worked at but two localities—Througham, near Bisley, on which account they are known locally as "Bisley Slates"*; and at Chalk Hill, near Eyeford, in the North Cotteswolds. Formerly they were extensively worked on Sevenhampton Common, where a large number of most interesting fossils were obtained; but now the workings are closed, and in places give the impression of ancient entrenchments.† There is one section on the Common that is still worth visiting, as a clay-bed near the top yields a number of fossils. The quarry is situated in a field a little to the left of the road from Whittington to Cleeve Hill, and near the first cottages.

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* *Proc. Geol. Assoc.*, vol. xiii (1893), pp. 126-127.

† T. Rupert Jones and C. D. Sherborne, *Proc. Bath Nat. Hist. Club*, vol. vi, p. 249.

‡ *Proc. Cotteswold Nat. F.C.*, vol. x, pt. 1 (for 1889-90), pp. 94-100.

§ *Ibid*, vol. ix, pt. 2 (1886-87), pp. 108-135

‖ *Mem. Geol. Surv.*, "The Jurassic Rocks of Britain," vol. iv (1894), pp. 245-246.

¶ *Proc. Geol. Assoc.*, vol. xiii, (1893), p. 126.

** J. Lycett, "The Cotteswold Hills" (1857), p. 93: *Quart. Journ. Geol. Soc.*, vol. iv (1848), pp. 185-186: *Proc. Cotteswold Nat. F.C.*, vol. i, p. 17.

†† "A Monograph of the Mollusca from the Great Oolite," *Pal. Soc.* (1850-54).

Away from the edge of the hills in the South and Mid-Cotteswolds the basement-beds of the Lower Division are less frequently exposed, and it is the White Limestone and Kemble Beds that are usually met with. Quarries are numerous around Kemble and Cirencester, and many are in work still; but each year they become fewer in number as the practice of introducing Clee Hill Dhu stone for metalling the roads becomes more prevalent. The White Limestone of the Upper Division is interesting as being frequently perforated by peculiar ramifying tubular "borings." Such rock is much prized for rockeries, and is known as "Dagham Stone," after Dagham Downs, where it is easily obtainable, being close to the surface. Fine sections through nearly the whole of the great Oolite are obtained in the railway-cuttings near Chedworth and Hampen. Near the former place‡ the stone has been extensively worked for dispatch to Salisbury Plain to make concrete for the military works there.

In the eastern portion of the district, at Milton—near Chipping Norton Junction—is the fine section at Grove's Quarry, where nearly the total thickness of the Great Oolite is exposed.§ The section is particularly instructive, in that it shows numerous unctuous clay-beds amid the limestones, which at Bath are so massive-bedded.

It is scarcely necessary to add anything more concerning the Great Oolite. The various sections have received considerable attention from Mr. H. B. Woodward, and have been recorded by him. It will be sufficient to refer the reader to his work, and to state that sections abandoned and in work are numerous in the hill-country of the Cotteswolds. For general purposes it will be sufficient to see the sections, say, at Farley Down, Minchinhampton Common, Sevenhampton Common, Chalk Hill, and Milton.

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* L. Richardson, "A Handbook to the Geology of Cheltenham," (1904), p. 161.

† *Ibid.*, p. 163; Sir R. I. Murchison, "Outline of the Geology of the Neighbourhood of Cheltenham," 2nd ed. by J. Buckman and H. E. Strickland (1845), pp. 18-21.

‡ In the railway-cuttings between Chedworth and Foss-Cross Stations.

§ R. F. Tomes, *Quart. Journ. Geol. Soc.*, vol. xli (1885), p. 171; L. Richardson, *Proc. Cotteswold Nat. F.C.*, vol. xvi, pt. 1 (1907), p. 32.

OXFORDIAN.

The Oxfordian, which succeeds the Cornbrash, extends across England from the coast near Weymouth to the cliffs between Scarborough and Filey, and varies in thickness from about 500 ft. at the southern end to some 200 ft. at the northern; while away from the Yorkshire coast, in the Howardian Hills, it measures but 80 ft.

The stage comprises three sub-divisions. First (and lowermost), is a bed of clay that varies in thickness from 10 ft. to 20 ft., but usually measures about 12 ft., and is occasionally called the "Kellaways Clay." At Gristhorpe Bay, in Yorkshire, it is from 6 ft. to 8 ft. thick, and so full of *Pseudomonotis (Avicula) echinata* as to have caused some geologists to regard it as best grouped with the Cornbrash. Second, is a series of sands and calcareous sandstones, the latter of inconstant thickness, but usually measuring—along with the sands—between 50 ft. and 70 ft., which is known as the "Kellaways Rock," because certain of its beds, which are richly fossiliferous, were quarried near the little village of Kellaways in Wiltshire at the time William Smith visited the neighbourhood*; and third, there is a great deposit of blue and grey clays, with occasional layers of earthy limestone and septarian nodules, that are imperfectly bedded in the upper portion, but thinly-laminated in the lower.

The whole stage admits of sub-division into four zones, those characterised by the ammonites *Cardioceras cordatum, Quenstedticeras lamberti, Cosmoceras jason,* and *Sigaloceras calloviense.* Except in Yorkshire, the limits of the zone characterised by the last-named ammonite approximately coincide with those of the Kellaways Rock; but in that county the sandy conditions prevailed longer, and the top-portion of the Kellaways Rock belongs to the succeeding *Jason*-Zone; while—with the exception mentioned—the lower limit of the *Jason*-Zone and the upper limit of the *Cordatum*-Zone respectively, contain the clay-portion.

Although sections are few and far between in Somerset and Gloucestershire, it is known that the thickness of the Oxfordian is on an average about 500 ft., and admits of the subdivision and zoning already noted. The actual junction with the Cornbrash is seen in an outlier at Weston, between Sutton Bingham and Closeworth, where about 4½ ft. of Kellaways Clay is seen to separate the Cornbrash from the bottom portion of the Kellaways Rock. Between Henstridge and Road village to the north of Frome. evidence of the Kellaways Rock has been obtained at Witham Friary, Marston Bigot, and Road Common,† but it is not until the railway-cutting at South Cerney, near Cirencester, is reached that there is anything like a good section. This section, which has been pictured and described by Allen Harker,* is still worth visiting, and is particularly interesting on account of the huge "doggers" that are embedded in the incoherent sands. In this neighbourhood the Kellaways Rock forms a well-marked bank, and there are poor exposures in the succeeding clay-beds in abandoned clay-pits close to the Thames and Severn Canal at Cerney Wharf (where small fossils are common in the shaly beds), and the dismantled windmill near Siddington St. Peter. Between Cirencester and Lechlade no sections are now available; heavy clay-land, furrowed by the small brooks into an undulating expanse, and frequently marshy, is, however, a sufficient index to its presence. "On the whole, the mass of the strata indicates fairly deep water, so far as terrigeneous deposits are concerned."

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* *Proc. Geol. Assoc.*, vol. xiv (1896), p. 340.

† *Mem. Geol. Surv.*, "The Jurassic Rocks of Britain," vol. v (1895), pp. 22-23.

The succeeding Corallian rocks were evidently laid down in shallow water, and their lithic characters are extremely variable. In Somerset and Gloucestershire they occupy a very small area, being present only in the neighbourhood of Wincanton, near Higher Hatherley, and about Stoke Trister and Cuckington. The only section of note recorded in this neighbourhood is on the little Higher Hatherley outlier, where, above Oxford Clay, is seen sandy clay with many fossils, surmounted by sands with concretionary masses of stone, the whole some 15 ft. to 20 ft. thick.

In Somerset and Gloucestershire there now occurs a great break, for Kimeridgian, Portlandian, Purbeckian, Wealden, and Vectian Beds are unrepresented, and the Selbornian deposits are the next found to be present. This break indicates a great upheaval, roughly of the nature of an uplift in the west or north-west, with a corresponding depression in the opposite quarter, and denudation. When subsidence set in again the successive members of the Cretaceous System extended farther and farther west over the planed edges of the Jurassic, Triassic, and Permian rocks.

SELBORNIAN.

Where the Selbornian is fully developed the zones that can be recognised in descending order are those of (1) *Aequipecten asper*, (2) *Schloenbachia rostrata*, (3) *Hoplites interruptus*, and (4) *Douvilleiceras mammillatum*. The term "Selbornian" embraces the deposits better known, perhaps, as the Gault and Upper Greensand, more precise attention to fossils having shown that the Upper Greensand is merely an arenaceous development of the upper part of the Gault.

The two lower zones of the Selbornian are absent from Somerset, which means that the *Sch. rostrata*-zone rests directly on the Mesozoic rocks, and is succeeded by that of *Aequipecten asper*. In the neighbourhood of Chard the lithic characters and approximate thicknesses of these two zones are :*

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* Allen Harker, *Proc. Cotteswold Nat. F.C.*, vol. viii, pt. 2 (for 1883-84), 176-187; *Proc. Geol. Assoc.*, vol. x (1887), p. 159.

CHERT BEDS: ZONE OF AEQUIPECTEN ASPER.	(*a*) Hard nodular calcareous grit, sandy and lumpy in places	8 to 9 ft.
	(*b*) Soft, greyish, fine-grained sand, with lines cemented into a sandstone by calcite, etc.	25 to 30 ft.
BLACKDOWN BEDS: ZONE OF SCH. ROSTRATA.	(*a*) Green sand, with shell-fragments and lumps of chert . .	seen 130 ft. or more.
	(*b*) Soft green and yellow sands	

These beds, capped with Plateau Deposits, constitute the greater part of the conspicuous Blackdown Hills, marked from a distance by Wellington Monument.†

Readily accessible, but not very satisfactory sections of the sand-portion of the Blackdown Beds, namely, (*b*), are situated at Hornsbury, a mile and a-half north of Chard, forming a small outlier covered with gorse-bushes. Siliceous shells, similar to those found farther west, are said to have been obtained here. A remote but excellent section of the sands is that on Staple Hill, south of Feltham. Farther west are the Blackdown Hills proper, where the sands are well-developed and contain those large masses of siliceous sandstone that have been so extensively worked in the past for scythe-stones. The beautifully-preserved fossils, which have made the name "Blackdown Hills" so familiar to the geologist, were mostly obtained when the pits along the brow, the escarpment which extends from Blackborough and Punchey Down to North Hill, in the south-western part of the area, were in full work in the early part of the last century. In dealing with old collections, it is well to bear in mind that the shells from Blackdown are always siliceous, never calcareous.

The Chert Beds are well seen at Snowdon Hill, west of Chard,‡ and again near Feltham—in the same place as that at which the underlying sands are so well exposed.

CHALK.

Outliers of Chalk, capped with Plateau Deposits, stretch from Crewkerne westwards to Buckland St. Mary, west of Chard. In the neighbourhood of Chard all three divisions of the Chalk have been noticed, but only the bottom zone of the Upper Division. The general succession is as follows:

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* W. A. E. Ussher, "The Geology of the Country between Wellington and Chard," *Mem. Geol. Surv.* (1906), pp. 37-42.

† Rev. W. Downes, *Quart. Journ. Geol. Soc.*, vol. xxxviii (1882), pp. 75-92 *Trans. Devon Assoc.*, vol. xiv (1882), p. 317 W. H. Fitton, *Trans. Geol. Soc.*, ser. 2, vol. iv, pt. 2 (1836), p. 233; A. J. Jukes-Browne, "Cretaceous Rocks of Britain," vol. i, p. 214; *Proc. Somerset Arch. and Nat. Hist. Soc.*, vol. xlix 2nd ed. (1903), pp. 1-11.

‡ H. B. Woodward, "Geology of England and Wales," 2nd ed. (1887), p. 392

Upper Chalk.	Chalk Rock	*Holaster planus*-Zone	seen 3 ft.
Middle Chalk.	White chalk, with scattered flints and hard nodular Chalk	*Terebratulina striata* and *Rhynchonella cuvieri*-Zones	80 to 100 ft.
Lower Chalk.	White Chalk with few siliceous nodules, grains of quartz and glauconite	*Holaster subglobosus*-Zone	65 ft.
	Fossiliferous basement-bed	*Hystrichoceras varians*-Zone	3 ft.

In the neighbourhood of Chard the bottom-most layer of the Chalk, 1 ft. thick, generally known as the "Chloritic Marl," is extremely fossiliferous, and has long attracted the attention of collectors. Mr. A. J. Jukes-Browne thinks that it is not equivalent to the Chloritic Marl of Wiltshire and the Isle of Wight, but—together with an overlying 2 ft. bed of glauconitic chalk—"the condensed representative of the lower part of the Chalk Marl."* It is well exposed at the Snowdon-Hill Quarry, within easy access of Chard. The whole of the Middle Chalk is present in the neighbourhood, and there is a quarry in it a mile west of Chard on the Honiton Road, while the bottom zone of the Upper Chalk is seen in a pit half-a-mile north-west of Combe St. Nicholas, on Combe Beacon Hill.†

Geological History after the Cretaceous Period.

After the deposition of the Chalk there was uplift in the north-west, and it is improbable that the greater portion of Gloucestershire was ever again entirely submerged. This uplift resulted in the planing of the uprising Chalk and—as the movement of elevation predominated—the dissection of the elevated mass. On the hills between the combes and valleys of the much-dissected upland west of Chard there is, above the plane of the Tertiary denudation, a wide-spreading deposit of "clay with flints." Here and there, however, occupying a position between it and the Chalk, are patches of gravel, with an occasional clay-bed that may be of Tertiary age; but the actual relations of the "clay with flints" and the gravel are very difficult to determine owing to the dissolution of the underlying Chalk causing a settling down and consequent admixture.‡ Again, in the neighbourhood of Frome, for example, at the little footbridge over the brook at Nunney Castle and at the cross-roads at Whatley Church, are sarsen-stones—remnants of the Eocene Beds that once stretched much farther west.

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* *Mem. Geol. Surv.*, "The Cretaceous Rocks of Britain," vol. ii, p. 110.

† A. J. Jukes-Browne, *Proc. Somerset Arch. and Nat. Hist. Soc.*, vol. xlix, p. 1.

‡ W. A. E. Ussher, "The Geology of the Country between Wellington and Chard," *Mem. Geol. Surv.* (1906), pp. 48-51.

Then for untold ages and until the present time the surface of Somerset and Gloucestershire has been undergoing denudation, and as the Neozoic deposits are removed an old land surface of hill and dale—carved out of the diverse, flexured strata of the Palæozoic Group—is being revealed and modified.

In Somerset and Gloucestershire there are very considerable deposits of gravel, sand, alluvium, and peat, several raised beaches and sunk forests, and a number of caves in the Carboniferous Limestone ridges.

No very definite relics of the Glacial Epoch in the forms of Boulder Clay or striated stones have yet been obtained, but it is quite probable that the remains so frequently found at the bottom of the Gravels around Gloucester, in the Avon Valley at Bath and Freshwater, and around Taunton, are of animals that roamed over the more congenial lowlands of the south-west, while rigorous glacial conditions obtained farther north.

A great deal more work* is necessary before the history of the Superficial Deposits of these counties can be written, and for the present purpose it must suffice to present the general facts as graphically as possible.

In Gloucestershire, north of Berkeley, the Superficial Deposits comprise (1) Quartzose Sand, with or without rolled débris of Inferior-Oolite and Liassic Limestones, (2) almost pure débris of such limestones, (3) "Northern Drift," which occurs in the Moreton Valley and along the line of the Severn, and (4) "hill-wash," on the flanks of the hills and in hollows on their summit.

The yellow quartzose sand is of considerable geographical extent. Mixed with some débris of the local rocks, it floors a considerable portion of the vale-land between Bredon and the Cotteswold Hills; † is of considerable thickness near Bishop's Cleeve, where it is worked in pits near the Church; constitutes the ground upon which the greater part of Cheltenham is built; is lodged on the northern slopes of Churchdown Hill; and spreads out over a large tract between that elevation and Robins' Wood Hill, near Gloucester, being exposed in several pits at Barnwood and alongside the railway near the Cemetery, Gloucester. From the mouth of the Stroud Valley it expands westwards in a >-shaped form, and, as at Barnwood, consists sometimes of almost pure sand and at others has mixed with it a considerable amount of rolled local Jurassic rocks.‡ Mammoth and other vertebrate remains have been found in the gravel and sand of this neighbourhood, as well as at Charlton Kings, near Cheltenham, while in some of the finer intercalations at Cainscross, Stroud, freshwater shells of existing species are not uncommon. On the hillsides and at various altitudes are deposits of aggraded Inferior-Oolite limestones; at Dursley, with intermittent layers of clay; while occurring in hollows on the edge of the escarpment or in depressions on the high ground, are accumulations of similar material; for example, at Gravel Farm, Haresfield, and on Cleeve Hill. Sand occurs and is worked at the southern end of the Moreton Valley,[*] but is redder than that in the Vale of Gloucester, and includes occasional rolled pieces of local rock and pebbles of more distant origin. When traced northwards the sands of the southern end of the Moreton Valley give place to accumulations of pebbles and rock-fragments foreign to the district, amongst which may be recognised flints, liver-coloured quartzites, quartz, jasper, chert and grit, and occasional pieces—as at Little Wolford—of Red Chalk. At Moreton-in-the-Marsh the "Northern Drift"[†] is very well developed, and spreads far and wide over the surrounding lowland, extending towards and over the neck of high ground pierced by the Mickleton Tunnel;[‡] but on the Cotteswold uplands pebbles are rare. There is an interesting section near Tangley, on the edge of the hills at the southern end of the Moreton Valley, over which there has been some discussion,[§] and on the high ground thence towards Burford quartz pebbles are not uncommon. The "Northern Drift" occurs on both banks of the Severn, capping such hills as Wainlode and Limbury[‖]; but away from the line of that river on the left bank they gradually die out,[¶] and their distribution in the fields is distinctly sporadic.

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* For general accounts see "Geology of East Somerset and the Bristol Coal-Fields" (1876), pp. 145-164, *Mem. Geol. Surv.*; W. C. Lucy, *Proc. Cotteswold Nat. F.C.*, vol. v, pt. 2 (1870), pp. 71-125; C. Callaway, *ibid.*, vol. xiv, pt. 3 (1903), pp. 183-194; L. Richardson, "A Handbook to the Geology of Cheltenham" (1904), pp. 190-200.

† L. Richardson, *Proc. Geol. Assoc.*, vol. xviii (1904), p. 407.

‡ E. Witchell, "Geology of Stroud, etc." (1882), pp. 85-99.

That portion of the Oxfordian which occurs in Gloucestershire is largely covered by very well-rolled débris of Jurassic rocks derived from the Cornbrash, Forest Marble, Great and Inferior Oolites situated to the north and north-west of its outcrop. There are pits in it at the cross-roads on Tudmoor, between Sharncott and South Cerney; at Maisey Hampton, where there is an occasional "Northern-Drift" pebble; and between Fairford and Kempsford, near Dunfield, and on the Kempsford-to-Welford Road, where pieces of flint are not uncommon and occasional "Northern-Drift" pebbles.[**] These deposits are situated close to the shore-line of the south-westerly extension of Mr. Harmer's "Lake Oxford."[††]

[*] L. Richardson, *Proc. Cotteswold Nat. F.C.*, vol. xvi (1907), p. 32; Hull, "Geology of the Country around Cheltenham" (1857), *Mem. Geol. Surv.*, p. 93.

[†] S. S. Buckman, *Proc. Cotteswold Nat. F.C.*, vol. xiv, pt. 2 (1903), pp. 113-118; T. M. Reade, *ibid.*, pp. 111-113; C. Callaway, *ibid.*, p. 118, and *Proc. Geol. Assoc.*, vol. xviii (1904), p. 406; A. E. Salter, *Proc. Geol. Assoc.*, vol. xix (1905), p. 38.

[‡] G. E. Gavey, *Quart. Journ. Geol. Soc.*, vol. ix (1853) p. 29.

[§] L. Richardson, *Proc. Cotteswold Nat. F.C.*, vol. xvi, pt. 1 (1907), p. 28.

[‖] W. C. Lucy, *ibid.*, vol. v, pt. 2 (1870), p. 81.

[¶] W. C. Lucy, *loc. cit.*, p. 105.

[**] A. C. Ramsay, "Geology of Parts of Wiltshire and Gloucestershire" (1858), *Mem. Geol. Surv.*, p. 45.

[††] *Quart. Journ. Geol. Soc.*, vol. lxiii (1907), Pl. XXXIV.

In Gloucestershire, south of Berkeley, I have not detected any Superficial Deposits, but in the Avon Valley at Bath[*] and Freshford are interesting river-gravels. The Freshford gravels are particularly interesting in that, in addition to the usual mammoth remains, they have yielded bones of such typically Arctic animals as the reindeer and musk-sheep.[†]

Here and there bordering the valleys of some of the more important rivers in the Vale of Taunton, or crowning tracts of Liassic rocks in the Vale of Ilchester, patches of gravel are found, which frequently contain the remains of extinct animals.[‡] In many places at and near Taunton and near Castle Cary (when the Castle Cary and Langport Line was being constructed)[§] such remains were found. Then on the coast at Birnbeck Cove[||] and Swallow Cliff,[¶] both near Weston-super-Mare, raised beaches, 3 ft. or 4 ft. thick, composed of waterworn pebbles and containing shells of existing species, occur. In the Carboniferous Limestone masses are caves yielding an interesting series of bones of animals of the Pleistocene fauna. The best known caves are those at Wookey, Banwell,[**] Uphill,[††] Burrington (Goatchurch Cave), Walton (near Clevedon),[‡] Durdham Down (Clifton),[§§] and the Great Doward, near Symonds Yat.[||||]

Buried beneath the great deposits of clay, gravel, sand, peat, and silt of Burnham and Huntspill Levels are here and there thin deposits of gravel, concerning which Mr. Ussher writes: " . . . We can only hint at the possibility of the contemporaneity of these gravels with the glacial gravels of South Wales, between hummocks of which patches of peat are often found."[¶¶] The available sections indicate that marsh peat may have flourished between these hummocks of gravel; but then followed a period of depression, during which blue clay, gravel and sand were deposited, succeeded by one of uplift that rendered conditions suitable for the growth of the now submerged forest at Stert Point, and may be at Westbury-on-Severn also.[***]

Subsidence again admitted the sea to the formerly-wooded tracts, and as far as Meare on the north side of the Polden Hills and Othery on the south side, we can picture the formation of the occasional shell-bearing sands of the Burtle Beds,[*] partially heaped up, no doubt, by the strong-blowing westerly winds.

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[*] C. Moore, *Proc. Bath Nat. Hist. Soc.*, vol. ii (1870), p. 37.

[†] Rev. H. H. Winwood, *Proc. Bath Nat. Hist. and Antiqu. F.C.*, vol. vi (1886-9), pp. 95 and 327.

[‡] W. A. E. Ussher, "The Geology of the Quantock Hills, etc." (1908), p. 76, *Mem. Geol. Surv.*

[§] Local newspapers.—L. Richardson.

[||] E. C. H. Day, *Geol. Mag.*, dec. 1, vol. iii (1866), pp. 115-119; see also *Proc. Geol. Assoc.*, vol. xi (1890), p. ccxi.

[¶] Sanders, *Rep. British Assoc.*, 1840, sections, p. 103.

[**] See Boyd Dawkins "Cave Hunting," pp. 292-314.

[††] S. H. Reynolds and E. Wilson, *Proc. Bristol Nat. Soc.*, n.s., vol. ix, pt. 3 (issued for 1900), pp. 152-160.

[‡‡] S. H. Reynolds, *Proc. Bristol Nat. Soc.*, Ser. 4, vol. i, pt. 3 (issued for 1906), pp. 183-187; H. N. Davies, *ibid.*, pp. 188-189.

[§§] E. Wilson, *Proc. Bristol Nat. Soc.*, n.s., vol. v (1885-8), p. 31.

[||||] L. Richardson, *Trans. Woolhope Nat. F.C.*, vol. for 1905, p. 68; Rev. W. S. Symonds, "Records of the Rocks," pp. 350-353.

[¶¶] W. A. E. Ussher, "The Geology of the Quantock Hills, etc." (1908), p. 84, *Mem. Geol. Surv.*

[***] E. W. Prevost. T. Mellard Reade, and others. *Proc. Cotteswold Nat. F.C.*, vol. xiv, pt. 1 (1901), p. 15.

The formation of banks by tidal action above the level of the ordinary tides, and the consequent conversion of the low-lying areas behind into a lake or morass, gradually evolved conditions suitable for the rapid growth of peat. The knolls of Burtle Sands were slowly encompassed by a treacherous land-surface. Now strong banks protect the "rhine"-traversed expanses of peat and prevent them from being inundated, and even in Roman times the surface of the peat must have been exposed and protected, for Roman remains are not infrequently found under at least six feet of river silt, etc.

The banks of the Severn from Tewkesbury to its embouchure in the Bristol Channel are, with few exceptions, margined by an ever-widening expanse of alluvium, with occasional associated peat-beds[†]; while on the Bristol Channel littoral between Clevedon and Bridgwater it is of great extent, and runs far inland along the lines of the rivers; while Blown Sand fringes the coast-line between the mouth of the Parret and Weston.

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[*] W. A E. Ussher in "Geology of East Somerset, etc." (1876), p. 163, *Mem. Geol. Surv.*.

[†] See W. J. Sollas, *Quart. Journ. Geol. Soc.*, vol. xxxix (1883), pp. 611-626.

CHAPTER XVI.

DORSET—INLAND.

By the late W. H. HUDLESTON, F.R.S., F.G.S.

IT is with deep regret that we have to record the death of the author of the following chapter, on January 28th, 1909. The names of the fossils are those used in the original report, in our Proceedings, but at the request of the late Mr. Hudleston the following notes on these fossil-names were prepared for him by Mr. S. S. Buckman. Editors.

Names used in this chapter.		Mr. S. S. Buckman's remarks.
Harpoceras moorei, Lycett	=	*Dumortieria latescens*, S. Buckman, *D.* aff. *moorei*, Lycett, sp.
,, *radians* (Schlotheim).	=	*Dumortieria pseudoradiosa*, Branco, sp.
Humphriesianus-zone	=	*Blagdeni* and *Niortensis* zones.
Zone of *Stephanoceras*	=	Zone of *Stepheoceras.*
Parkinsoni-zone	=	Upper Beds of Inf. Ool.
Zone of *Cosmoceras*	=	Zone of *Parkinsoni.*
Harpoceras concavum	=	*Ludwigella concava*, J. de C. Sowerby, sp. *Graphoceras v-scriptum*, *G. stigmosum*, *Lucya cavata*, *L. magna*, etc., S. Buckman.
Section *Harpoceras*	=	Family *Hildoceratidæ* — Genera *Witchellia*, *Sonninia*, etc.
,, *Stephanoceras*	=	*Stepheoceras*, *Teloceras*, *Cadomites*, *Normanites*, etc.
,, *Cosmoceras*	=	*Parkinsonia*, etc.
Zone of *Cosmoceras parkinsoni*	=	Zone of *Parkinsoni* = zones of *Garantiana garantiana*, *Strigoceras truellii*, *Zigzagiceras zigzag.*
Zone of *Stephanoceras humphriesianum*	=	Zones of *Blagdeni* and *Niortensis.*
Harpoceras sowerbyi	=	*Sonninia* of the *S. sowerbyi* type.
Stephanoceras blagdeni	=	*Teloceras banksi*, Sow. *T. blagdeni*, Sow.
Sphæroceras sauzei	=	*Otoites sauzei.*
Harpoceras edouardianum	=	*Dorsetensia edouardiana.*
,, *cycloides*	=	*Pœcilomorphus cycloides.*
,, *murchisonœ*	=	*Ludwigia murchisonæ.*
Perisphinctes martinsii	=	Same.
Ammonites dorsetensis, Wright	=	*Parkinsonia dorsetensis.*
Oppelia truellii	=	*Strigocerœs truelli.*
Sphœroceras brongniarti	=	Same.
Harpoceras adicrum, Waagen	=	*Sonninia acanthodes* and other spinous spp.
Lytoceras confusum, Buckman	=	*Megalytoceras confusum*, S. Buckman, sp.
Harpoceras-beds	=	*Murchisonæ*, *bradfordensis*, *concava*, *discites* zones.
H. var. bradfordiensis, Buckman	=	*Brasilia bradfordensis*, S. Buckman, sp.

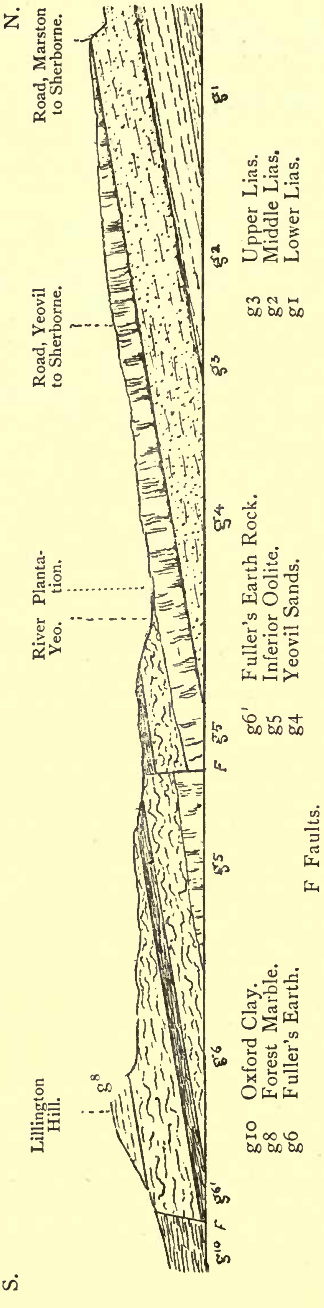

Fig. 58.—Section Across the Valley of the Yeo, 1½ mile west of Sherborne. (*Reduced from Bristow's Section.*)

Sherborne District.

The inland sections of this county have not, up to the present, received much attention from the Association. There was, however, an excursion to Sherborne on May 25th, 1885, the writer acting as Director.*

The party met in the Museum of the King's School at Sherborne, at 12.30 p.m., and was received by the Rev. E. M. Young, M.A., Head Master.

The Director gave a short sketch of the geology of the district. He reminded the party which had travelled down from London how complete is the sequence of the Oolitic rocks in the traverse from the Vale of Wardour to the Sherborne Valley. Every series (or formation) is more or less developed, except the Great Oolite Limestone, which is probably represented in time by part of the Forest Marble, and by the upper portions of the Fuller's Earth.

After crossing the county boundary at Semley not a single fault is traversed by the London and South Western Railway until we arrive within 2½ miles of Sherborne, when a fault, running nearly north and south, occurs in the Inferior Oolite, and may be traced as affecting all the Oolitic series, and even displacing the Greensand and Chalk farther south. A marked change in the stratigraphy of the district occurs here. East of this fault, which throws out a branch towards the village of Oborne, the escarpments face the west, but shortly after the fault is crossed it is seen that the escarpments are beginning to face the north, and that is entirely the case by the time that we reach Sherborne, where all the beds have a steady southerly dip, though, of course, a considerable amount of rolling and displacement may be noted.

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* *Proc Geol. Assoc.*, vol. ix, p. 187.

This southerly dip may be gathered from a study of the section across the Valley of the Yeo (Fig. 58), to which the attention of the members was directed. The hills on the south side of the valley are thus formed by the escarpments of the Fuller's-Earth, the Fuller's-Earth Rock, the Upper-Fuller's-Earth, and the Forest Marble, whilst the hills on the north side of the valley are formed by the dip-slope of the Inferior Oolite ascending towards its escarpment, which attains along the line of section a height of about 500 ft. above sea-level. Owing to the change in outcrop previously noted the Inferior Oolite escarpment presents a noble sweep of high ground which embays the Vale of Somerset. From some of its salients magnificent views may be obtained, only bounded by the Mendips on the north and by the Quantocks on the west. The massif, which is formed by the Inferior Oolite and Sands, has been cut transversely about three or four miles west of the line of section, between Yeovil junction and the town of Yeovil, and through the gorge thus formed the drainage of the Upper Yeo finds its way into the low-lying basin of South Somerset. So much for the physiography of the country round Sherborne.

Perhaps the most characteristic formation of the district is one to which, without begging the question, the name of *Yeovil Sands* would best apply. Judging from wells and exposed sections, a thickness of 150 ft. had been roughly assigned to these sands, which vary somewhat in character according as the hard calciferous bands and doggers are plentiful or scarce. The Director had discovered a very rich shell-bed in these "Sands" in a quarry at Stoford, near Yeovil Junction. It was probably about 30 ft. or 40 ft. below the base of the Inferior Oolite Limestone. The section may be detailed as follows:—

SECTION IN THE "SANDS" AT STOFORD.

	ft.	in.
a. Soft yellowish sands in thick beds, separated by thinner bands of hard blue calciferous grit; no fossils seen. .	30	0
b. A shell-bed like Forest Marble stone, with abundance of Monomyaria, and some Dimyaria. *Trigonia angulata*, *Tancredia* near to *donaciformis*—Univalves rare—*Harpoceras moorei*, Lyc. and *H. radians*, Schlot. are the prevailing Ammonites	2	0
Total in quarry	32	0

Without troubling themselves about any of the higher beds, the attention of the Members should, the Director said, be devoted to the Inferior Oolite Limestone, and he gave a short history of the various interpretations which had up to that time been suggested.

The Director stated he had obtained very clear evidence that the "fossil-bed" of North Dorset was on three entirely different horizons in such quarries as Oborne, 3½m. north-east; Half-way House, 3m. west; and Bradford Abbas, 4½m. west-south-west of Sherborne. At Oborne the principal "fossil bed" was in the *Humphriesianus*-zone, or in what he should prefer to call the zone of *Stephanoceras*,* and this was the case near Sherborne itself. At Half-way House the principal "fossil bed" was in the *Parkinsoni*-zone, or zone of *Cosmoceras*,* whilst at Bradford Abbas it was in the so-called *Sowerbyi*-subzone, characterised by an extraordinary abundance of *Harpoceras** *concavum*. Hence, if we are desirous of a local name for this rich but limited group, we might speak of the *concavus*-beds.

Now the evidence that he was about to adduce had the advantage of having been obtained from a very few feet of rock. Instead of the many hundreds of feet presented by the Inferior Oolite of Yorkshire, distended as it was with a quantity of estuarine shales and sandstones, instead of 230 ft. of mixed marine limestones at Leckhampton, only 70 miles off, we here have the Inferior Oolite comparatively in a nutshell, the whole thing having been "boiled down" as it were, so as to present a quarry face of very accessible dimensions. We must not always estimate the value of a thing by its volume; nay, this paucity of sediment is an actual advantage. There is a single bed in the Bradford Abbas quarry no more than two feet thick, which, to a palæontologist, is worth more than an entire section in the Cotteswolds. But this is only an example of similar beds on other horizons of the Inferior Oolite of this district, where the shells, instead of having been ground up under the influence of strong currents and breakers, seem to have been deposited side by side in waters of considerable tranquillity.

But what the Director especially desired to point out was the very great—the almost total—change undergone by the Ammonite fauna within very moderate thickness of rock. The extraordinary difference had been noted by several observers, and was known to all collectors and quarry-men; but some had set it down to nothing more than mere local change. If such was the case, it was curious that the same relative position of the three well-known groups should always be duly preserved. The beds which swarmed with the section *Harpoceras*, when visible, were always at the bottom. Those which were characterised by the section

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* These were the names of the corresponding Ammonite sections at the time (1885). See Mr. Buckman's note at the beginning of this chapter.

Stephanoceras, wherever they occurred—and they were frequently absent in the full development—were always above the *Harpoceras* Beds, but also always below the beds which were characterised by the section *Cosmoceras*. These facts, together with the wonderfully sharp and sudden change in the Ammonite fauna, he hoped to be able to prove in the quarries which the Members would visit in the afternoon.

The party drove to Frogden Quarry, Oborne, and the following is the reading of the section which was offered by the writer at that time:

SECTION AT FROGDEN QUARRY, OBORNE, 1¾ MILES N.E. OF SHERBORNE.

		ft.	in.
ZONE OF COSMOCERAS PARKINSONI.	Soil and roots	1	0
	a. Pale fissile limestones	2	0
	b. Courses of brown sandy limestone, with intervening soft-stuff	4	6
ZONE OF STEPHANOCERAS HUMPHRIESIANUM.	*c*. "Top stone," or *Cadomensis* bed, a sandy, iron-shot oolite	5	0
	d. Main beds of the *Humphriesianus*-zone, brown iron-shot oolites		
SAUZEI BED.	*e*. Marl with green grains, *H. sowerbyi* and other species of *Harpoceras* in abundance; *Sphæroceras sauzei* occasionally; many univalves	0	6
	Total in quarry	13	0

DETAILS OF THE BEDS.

a. *Cosmoceras parkinsoni* said to occur here, but probably rare. These are the commencement of the "freestones" which come on more extensively on the dip. In the quarry above Oborne village, on the opposite side of the valley, 18 ft. of massive limestones, with brownish sandy partings, may be seen on this horizon.

b. These beds divide as follows:

	ft.	in.
Stone down to a shaly bed, with *Belemnites*, *Rhynchonella spinosa*, *Terebratula ferryi*, and *Ancyloceras*	1	7
Stone down to a shaly layer with small var. of *T. sphæroidalis*, *Belemnites*, etc.	1	2
Stone to a bed of soft brown sandy limestone, which contains a peculiar form of *Cosmoceras*, and ? *Perisphinctes* .	1	9
	4	6

c. "Top Stone" (*Sphæroidalis* or *Cadomensis* bed), regarded usually as the highest bed of the *Humphriesianus*-zone; but there is a most curious assemblage of Ammonites. *Cosmoceras*, *Oppelia*, *Perisphinctes* predominate, though the true *Parkinsoni* probably hardly occurs. *Stephanoceras* not numerous, and usually small. It may be regarded as a true passage bed between the zones of *Parkinsoni* and *Hum-*

phriesianus. Numerous univalves, and many species of *Astarte.* Monomyaria not abundant.

d. "Main beds of the *Humphriesianus*-zone." Towards the centre a layer of the *Stephanoceras blagdeni* (on end); towards the base a layer of large *S. humphriesianum* (flat). *Stephanoceras* and *Sphæroceras* in great abundance, with a few *Oppelia* and *Lytoceras.* *Harpoceras* rare, and very peculiar (one near to *H. edouardianum); H. cycloides.* Gasteropoda and Lamellibranchiata tolerably numerous. *Terebratula sphæroidalis* abundant.

e. "Marl with green grains." The matrix is favourable for the extraction of shells. Gasteropoda abundant, whence this is sometimes called the "univalve bed." It is largely made up of brownish iron-shot stone, which includes patches of marly stuff, with green grains. Amongst the Ammonites the section *Harpoceras* largely prevails. *Sphæroceras sauzei* occurs rarely. *Stephanoceras* and *Oppelia* small and infrequent. The fossils differ considerably from those of the so-called *Sowerbyi* bed at Bradford Abbas.

It has, however, since been recognised that this latter is a complete misnomer, and the great fossil-bed of Bradford Abbas is now generally known as the *concavus* bed.

The party then moved on to Halfway House, situated on the top of a sharp rise, where there had been extensive quarrying for many years past. Just before entering the main quarry the members had an opportunity of inspecting a fault which brings the basal beds of the Inferior Oolite Limestone against the "Sands." This exposure is valuable, as showing the bottom of the "Dew" bed, together with a few feet of the "Sands" on which it rests.

Section at Halfway House—Quarry close to High Road on the North.

		ft.	in.
Zone of Cosmoceras parkinsoni.	Additional beds on south side of road, say .	10	0
	a. Soil and top rubble.	3	6
	b. Alternations of freestones and dirty soft-stuff	9	6
	c. The "fossil bed." *C. parkinsoni* very large	2	0
? Zone of S. humphriesianum.	*d.* "Soft shell-bed" with irony band below, variable, say	0	4
Zone of H. murchisonæ.	*e.* Upper *concavus* bed	2	0
	f. Lower *concavus* bed	2	2
	g. "Dew bed," a calciferous grit, variable, say	1	6
	Total in quarry	21	0
	Sands and calciferous grits to bottom of well, say . .	125	0

Details of the Beds.

[*] *a.* and *b.* There may be about 22 ft. of limestone and soft stuff above the "fossil bed." These freestones are not very fossiliferous,

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[*] The letters *a, b,* &c., are not used to indicate the same beds as the *a, b,* &c., of the other quarries. Each quarry stands by itself as regards lettering.

but contain *Cosmoceras parkinsoni*, and *Perisphinctes martinsii* occasionally, along with *Nâutilus* (?) *latidorsatus*. Remains of Crustacea are sometimes found.

N.B.—In the "freestones" at Sherborne a fine specimen of *Megalosaurus bucklandi* was found on the occasion of the excursion. These beds help to form the great thickness of the Inferior Oolite at Sherborne.

c. There are two principal lines of *Cosmoceras parkinsoni;* the lower one contains the best specimens for cutting and polishing. This was the *A. dorsetensis* of Dr. Wright. It presents certain differences from the specimens in the Bridport district. Fine specimens of *Oppelia truellii* likewise occur—also a small, fine-lined *S. humphriesianum*. The rock is a buff-coloured limestone sparingly ironshot, and the best in the quarry for univalves.

d. "The soft shell-bed," etc. The upper portion of *d*, *i.e.* to say, the "soft shell-bed" itself, seems to form part of the block in which the great *C. parkinsoni* occurs; without, however, belonging to it. The development is extremely variable, and its connection with a thin ferruginous band beneath is irregular and uncertain. The soft shell-bed is sometimes absent. The most common fossil is *Astarte obliqua;* it contains minute specimens of *Stephanoceras* near to *humphriesianum*, and a medium-sized *Sphæroceras brongniarti*, Sow., is characteristic.

At Wyke Park quarry ¾ mile south, the ferruginous beds, 8 in. thick, are believed by Mr. S. S. Buckman to represent the *Humphriesianum* bed of Sherborne, etc.

e. In this bed are fine specimens of *Harpoceras adicrum*, Waagen, in position. This is probably the "*Ammonites variabilis*" of some writers. *T. perovalis*, var. *amplà*, occurs. But few univalves.

f. The thick bed where we find *Amm. concavus*, and "*jurensis*." This latter is the *Lytoceras confusum* of S. S. Buckman; an enormous specimen may be seen (May, 1885) in position in the old quarry—*T. perovalis*, var. *ampla*, and *Rhynchonella ringens*. But few univalves.

g. The "dew bed," which forms the bottom of the limestones, or top of the sands, is at the base of the quarry, and occupies a lower horizon than the "dew bed" at Frogden Quarry, Oborne.

Very interesting exposures are obtained in an old quarry face which leads up towards the escarpment on the north, and where all the beds above detailed may be seen gradually cropping out, until the *Harpoceras* beds (here called the *concavus*-beds from the extraordinary profusion of *H. concavum*, Sow.) form the surface of the field.

A rapid drive from Halfway House brought the party to the celebrated quarry in Bradford Abbas parish, close to the house occupied for so many years by the late Professor Buckman,* a mile and a half south-south-west of Halfway House.

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* When the Association visited this district 14 years previously Professor Buckman was one of the Directors. On the second day of the Excursion he conducted the party, which was quartered at Pen Mill, near Yeovil, through the Babylon Hill cutting, thence to Halfway House and Sherborne, and lastly to "a small quarry on his farm, where a quarryman exhumed with a pick in a few minutes great numbers of fine ammonites." Professor Buckman entertained the party at dinner, and afterwards expounded his views on the geology of the district. (See *Proc. Geol. Assoc.*, vol. ii, p. 249.) Mr. Hudleston, in replying to a vote of thanks for his services as one of the Directors of the later Excursion, alluded to the fact that he was the only member of the Association who had been present at both Excursions.

SECTION AT BRADFORD ABBAS (EAST HILL QUARRY).

Zone	Sub-zone	Bed	ft.	in.
ZONE OF COSMOCERAS PARKINSONI.		*a.* Whitish limestone in beds which are not very fossiliferous, though *C. parkinsoni* occurs rarely, and mostly towards the base	6	6
		b. Marl bed with *Terebratula morieri* and *Rhynchonella parvula*	0	6
? ZONE OF S. HUMPHRIESIANUM.		*c.* The "rotten bed" with large *Astarte.* Very small Ammonites, mostly *Stephanoceras;* thickness variable, say	0	6
ZONE OF H. MURCHISONÆ.	SUB-ZONE OF H. CONCAVUM.	*d.* Irony stone	0	6
		e. The great shell bed of Bradford Abbas with *H. concavum* in abundance. Full of univalves. A yellowish iron-shot oolite	2	0
		f. The paving-stone or *Murchisonæ* bed proper	1	1
		g. The "Dew bed"	1	2
		Total in quarry	12	3

DETAILS OF THE BEDS.

c. There is an enormous number of bivalves, both *Astarte obliqua* and *A. excavata*, large *Modiola, Lima pecteniformis*, etc., *Terebratula phillipsii*. Towards the south end of quarry this bed is seen to increase on the dip, but, relatively to the thickness, the fossils are less abundant. It probably represents the "soft shell-bed" of Halfway House.

d. According to Mr. S. S. Buckman this may be the representative of the marl with green grains (*Sauzei* bed) of Oborne (*e* of that section).

e. More good fossils have been extracted from this bed than from an equal weight of any other stone in England.

f. The "paving-stone bed" is a slabby ironshot oolite, which comes off just above the "dew bed," and is used for gutters, etc. The true *Harpoceras murchisonæ* occurs here, as also the var. *Bradfordiensis*, S. S. Buckm. That author says of *H. murchisonæ* that it "marks a distinct zone, which is just on the top of the sands or passage-beds. This zone is about a foot thick at Bradford Abbas, but about 3 to 4 ft. at Corton and Hawthorn Downs." We have lately found the true *H. murchisonæ*, Sow., below the *concavus*, or "fossil bed," in the Wyke cutting, *i.e.* to say, in a position exactly corresponding to its place here. Small corals occur in this bed.

There was no time to visit the prolific little quarry at Stoford, just beyond Yeovil Junction Station, where the Inferior Oolite Limestone is worked; but it may be observed that the total thickness of Inferior Oolite Limestone between the "Sands" and the Fuller's Earth at this place does not much exceed 5 ft. As we have a complete section here, there is no question about loss of beds from denudation. This was the original development, and thus we see that the Inferior Oolite Limestone has diminished from 35 or 40 ft. at Nethercombe, near Sherborne, to 5 ft. at Stoford, a distance of five miles west-south-west. At Stoford the *Parkinsoni*-zone is about 4 feet thick, with a shelly bed at base, which may represent something more than the *Parkinsoni*-zone, though there is no certain indication of the *Humphriesianus*-beds, which seem generally wanting when we reach any distance west of Sherborne. On the other hand, probably less than half of the Inferior Oolite in Stoford quarry belongs to the *Murchisonæ*-zone, or to the sub-zone of *H. concavum*. The fact is that the "fossil bed" corresponds pretty closely to one at Bradford Abbas. The peculiar fossil *Cirrus* is plentiful just above the "Dew-bed."

WAREHAM DISTRICT.

We pass now to the Wareham District in order to notice a recent boring which throws much light on the geological structure of the county.

Bovington Camp lies on the edge of Wool Heath and a mile or two from that village. Since the War Office was not satisfied with the water supply afforded by an ordinary well in the Bagshots, it was determined to bore through the Bagshots into the Chalk for an Artesian supply. The results were very satisfactory, from an economic point of view, whilst the operations afforded a favourable opportunity for studying the several formations in the upper part of the Dorset Syncline.*

The following is a summary of the results:

	ft.	in.
Surface beds, chiefly Plateau-gravel	14	0
Bagshot beds	151	0
Lower Tertiaries (*i.e.*, London Clay and Reading beds)	115	0
Chalk	446	0
Total	726	0

The Bagshot Beds are much thinner here, near their outcrop, than they are likely to be lower down the country, say, on the meridian of Wareham.

The following are the details of the beds above the Chalk:

SUPERFICIAL.

		Thickness. ft.	Thickness. in.	Depth. ft.	Depth. in.
	Soil	1	0		
1.	Marly clay	2	0		
2.	Gravel. Plateau-gravel with yellow flints.	11	0		
				14	0

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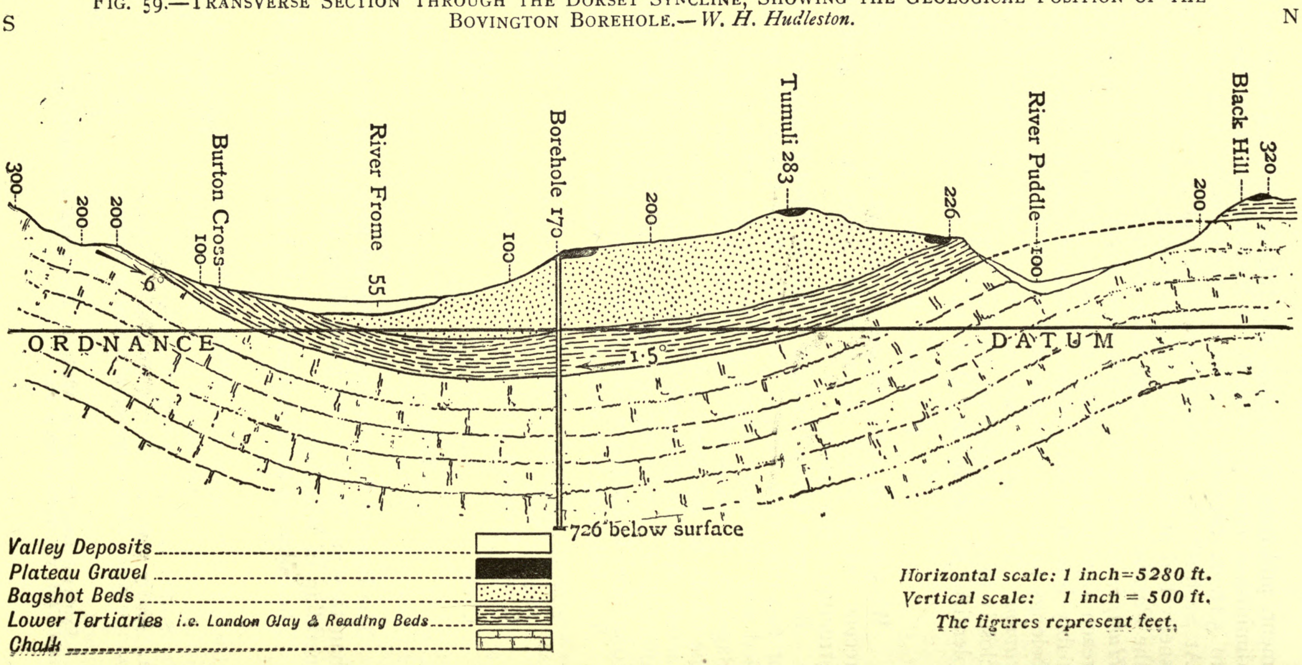
* Extracted from "Artesian Wells in Dorset and Elsewhere," *Proc. Dorset Field Club*, vol. xxviii (1907), p. 185.

FIG. 59.—TRANSVERSE SECTION THROUGH THE DORSET SYNCLINE, SHOWING THE GEOLOGICAL POSITION OF THE BOVINGTON BOREHOLE.—*W. H. Hudleston.*



BAGSHOTS.

No.		Thickness ft.	in.	Depth. ft.	in.
3.	Sand with loam bands. Coarse, yellowish sand of uniform sized grain invested with ferric oxide. The "loam bands" consist of fine white powdery loam	20	0	34	0
4.	Coloured clay and sand. Fine sediments, mostly discoloured and clayey	10	0	44	0
5.	Brown sand. Loose sugary sand	4	0	48	0
6.	Light grey sand	3	0	51	0
7.	Loose grey sand. Sharp quartzose, clean.	7	0	58	0
8.	Coloured sandy clay. Whitish clay, slightly stained with iron; sets hard	4	0	62	0
9.	Coarse sand. Loose, yellowish, coarse quartzose sand with small fragments of soft white silica, and one or two largish pebbles of lignite (See No. 17)	[water-level 85] 29	0	91	0
10.	Coloured clay and sand. "Two-ball" pipeclay	6	0	97	0
11.	Live sand. Loose yellowish sand, rather coarse and with specks of soft white silica	24	0	121	0
12.	Blue clay. A fine, unctuous, grey clay, like some of the grey pipeclays	12	0	133	0
13.	Coloured clay and sand	4	0	137	0
14.	Live, coarse sand. A very clean, angular quartzose grit, said to be full of water. Would make good building sand	18	0	155	0
15.	Brown coarse sand (live). Similar to the above, but dirty	10	0	165	0
	Total Bagshots	151	0		

LOWER TERTIARIES.

No.		Thickness ft.	in.	Depth. ft.	in.
16.	Sand and pebbles. Coarse, dirty greyish sand with black flint pebbles (of the Blackheath type), and some small buff pebbles of another material	1	0	166	0
17.	Sand and wood. Fragments of lignite	0	6	166	6
18.	Clay, sand, and pebbles	4	6	171	0
19.	Dark sandy clay, hard	9	0	180	0
20.	Coloured clay and pebbles, reddish	5	0	185	0
21.	Dark sand and clay. Dries pale grey and sets rather stiff	42	0	227	0
22.	Dark clay and stones. The stones are of irregular shape (?) corroded flints.	1	0	228	0
23.	Live sand. Fine, pulverulent, grey sand, not very loose	19	0	247	0
24.	Coarse sand and pebbles. live (*i.e.*, water).	5	0	252	0
25.	Mottled clay. Light brown in colour	5	6	257	6
26.	Hard dark clay and sand	4	6	262	0
27.	Hard grey sand with some clay, sets like a sandstone	13	0	275	0
28.	Green sandy clay and flints at bottom. An earthy green-sand ranging from pale green to darker green; the flints are green-coated, mostly unworn and somewhat corroded.	5	0	280	0
	Total Lower Tertiaries	115	0		

Owing to the method of boring it was not possible to ascertain whether the Chalk is fossiliferous here so that no question as to horizon can be entertained. Assuming that the usual thickness of the Chalk in Dorset is about 900 ft., the bottom of the borehole is just half-way through that formation. There is no supply of water in the topmost Chalk until a depth of 70 ft. was reached, but the first great supply was obtained a little below 400 ft., when the water level rose to within 96 ft. of the surface. The artesian pressure, therefore, was equal to raising a column of water nearly 200 ft. into the Tertiaries in addition to 70 ft. of waterless Chalk. The War Office not being satisfied with the Upper Water Supply, boring was continued, when a lower and increased water supply was obtained, bringing up the total to 60,000 gallons per day, and the water level was raised to 93 ft. 6 in., below the surface. It should be noted here that hydrostatic pressure may, to a certain extent, be reduced by springs on the south side of the syncline, such as those outside Wool, which are about 75 ft. above O.D. Moreover in that direction the protective cap of Lower Tertiaries soon fails (see Fig. 59). The main water occurred between 675 ft. and 685 ft. from the surface.

When we come to study the geological position of the Bovington Borehole, the measurements of the Borehole section, in conjunction with the surface plotting based upon the ascertained contours, enable us to obtain a fairly accurate conception of the prevailing conditions. The true axis of the tectonic syncline (see Fig. 59), can only be fixed approximately, but in this case it probably almost coincides with the axis of the Frome valley, which here runs very nearly in the trough of the syncline. On the meridian of Worgret, near Wareham, on the other hand the bed of the Frome lies a long way south of the synclinal axis. Generally speaking, the southern limb of the Dorset syncline is shorter, and, therefore, steeper than the northern limb. In this case a northerly dip of 6° is assigned to the south limb above Burton Cross, on the strength of dips observed in the Chalk near Wool. According to certain calculations, there is reason to believe that the northern limb in the neighbourhood of the Borehole has a dip from 1.5° to 2° southwards, taking a sort of average, although there may be subsidiary folds within the general syncline. This is in conformity with the general rule that the dip of the northern limb is at a lower angle than that of the southern one.

From the Bovington Borehole to the margin of the Chalk escarpment near Bulbarrow is a distance of about 12 miles in a northerly direction, and if we deduct 3 miles for areas covered by Tertiaries along this line, there remains 9 miles of Chalk outcrop on which the rain may fall directly to feed its underground waters. It is well known that a large percentage of the water which falls on this absorbent formation sinks into it instead of flowing over the surface as is the case with clays. Moreover, the rainfall on the North Dorset downs is much heavier than in the Frome valley, and still more so in comparison with Weymouth. Hence, there is an abundant supply in the region lying to the north of the Borehole, and assuming the preponderance of the southerly dip, which may be taken for granted, this water in its underground passage is bound to find its way south until its progress is arrested by the pressure of water from the opposite limb of the syncline. Meanwhile, it is kept down by Tertiary Beds, &c., having a thickness of 280 ft. Yet, notwithstanding these advantages, the pressure can only be regarded as sub-artesian, since the water fails to reach the surface by some 93 ft.

We may conclude the present chapter with a short notice of the very interesting hill named Creechbarrow, though it has not, up to now, been visited by the Association.

This hill is a very prominent object throughout the northern half of the Isle of Purbeck and is especially conspicuous from the neighbourhood of Wareham, where it stands out in front of the long Chalk range running through the centre of the so-called "Isle." It is composed entirely of Tertiary Beds, and this circumstance renders the hill all the more peculiar, since it rises rapidly from the 300 ft. contour to an elevation of 637 ft., almost equalling that of the highest part of the Chalk ridge behind it. Except in this one spot the Tertiary Beds of the Isle, which lie on the dip slope of the Chalk ridge, do not as a rule exceed 300 ft. in elevation, and thus the exceptional elevation of this subconical hill constitutes a topographical anomaly for which it was difficult to account.

The first Geological Surveyors, recognising the difficulty of explaining these facts, represented the area occupied by the hill as consisting of London Clay enclosed in a kind of forked fault with just a capping of Bagshots at the summit. According to the more recent survey the whole area is coloured as Bagshot, and no faults are shown. This latter plan is more in accordance with the facts, but neither the map nor the accompanying memoir afford us much information as to the causes which have led to the formation of this very peculiar hill.

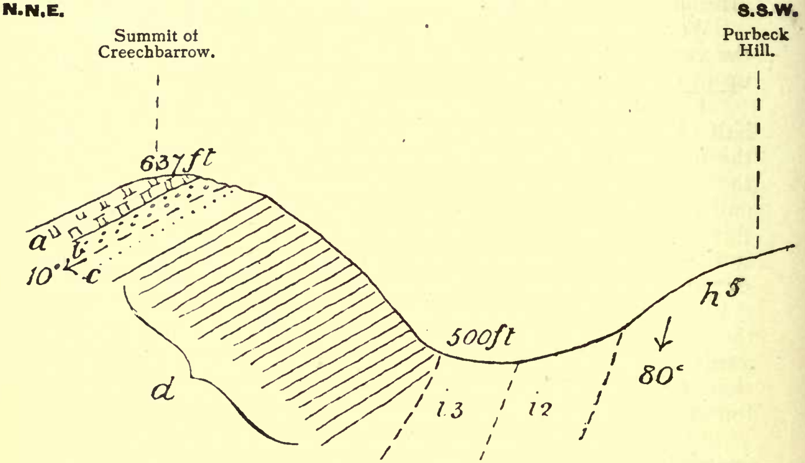
On the 21st August, 1901, the members of the Dorset Field Club had an excursion to West Purbeck, when the writer, after pointing out the anomalous character of the hill, offered some remarks as to its possible origin, and promised further to investigate the subject.

With the kind consent of the owner of the property, Mr. Bond, this work was undertaken in the following October, when it was discovered that the summit of Creechbarrow consists of an indigenous tufaceous limestone, containing some fresh-water fossils, and associated with beds of fine sedimentary material.

But this fine material is itself associated with masses of concretionary manganese, and especially with very large flints (Cretaceous) up to 30 lbs. in weight. There are also regular beds of flint in the series. The whole group is so very different to anything known in the adjacent Pipeclay Series of Bagshot age that the writer gave it the name of the *Creechbarrow Series*, so that its age might not be prejudged.

On the slopes immediately below the summit of Creechbarrow there is a considerable amount of talus, where natural are mixed with artificial objects, the latter being the result of the degradation of the keeper's lodge, which once occupied the summit. A pit was dug on the very top, showing a vertical section of about 7 ft. On the one side was the solid concretionary limestone *in sitû*, and on the other an artificial rubble mainly derived from the limestone.

FIG. 60.—GENERALISED SECTION OF CREECHBARROW (SOUTH SIDE).—*W. H. Hudleston.*



a—*d*. Creechbarrow Beds. *a*. The hill-top limestone. *b*. Sands with calcareous concretions. ——— Bed of flints. *c*. Sands below the flint beds. *d*. Beds not specially determined, mostly sandy. *i* 3. London Clay. *i* 2. Reading Beds. *h* 5. Chalk.

It is clear that the summit has been artificially flattened, and certain courses of dressed Purbeck stone remain as evidence of foundations. At what period this was *first of all* done it is impossible to say, but we are justified in supposing that, before human interference with such a prominent feature of the landscape, the limestone rock stood out like a needle, or tooth, above the encompassing greensward. This limestone forms the summit of Creechbarrow, and it is terminated towards the south by what may be regarded as an escarpment, of which the annexed figure is a generalised section.

From a series of observations, the dip of the beds on the summit was fixed at from 10°-12° approximately north-north-east. The following sequence at or near the actual summit may be accepted as fairly correct:

		ft.	in.
1.	Tufaceous limestone	7	0
2.	Softish tufaceous limestone	2	6
3.	Passing downwards into sands full of calcareous concretions	4	0
4.	Band of yellow clayey sand	0	6
5.	Loose buff-coloured sands	5	10
6.	Layer of large flints of the Creechbarrow type	1	0
7.	Pale buff-coloured sands (not bottomed)	4	0
	Total	24	10

When followed on the dip the above divisions cannot be identified, and there is no doubt that considerable local changes take place within short distances. There are indications that the limestone has been worked for marl towards the north, usually near the 500 ft. contour, and no limestone has been found below this elevation. Moreover, it is a curious circumstance that, although flints of the Creechbarrow Series are found on the lower slopes in such numbers as to give rise to the erroneous idea that they had been derived from Plateau-gravel, yet no fragments of the limestone occur on the surface of the lower slopes nor yet in any of the adjacent buildings.

Whilst referring to the changes which occur in the Creechbarrow Beds, attention might be drawn to their development on the eastern spur of the hill. This spur is a conspicuous object from the north-east side, since it breaks the regularity of the conical outline as seen from Furzebrook:

PIT ON THE EASTERN SPUR OF CREECHBARROW.

		ft.	in.
a.	Sandy earth with flints	0	6
b.	Flint gravel	3	6
c.	Buff, ferruginous sand with manganese nodules	2	6
	Total section	6	6

The flint-gravel (*b*) of this section is the thickest deposit of the peculiar gravel of Tertiary age as yet discovered on Creechbarrow. To anyone accustomed to the extremely fine deposits of the neighbouring Bagshots (including the Pipeclay) such a mass of bedded coarse material must come as a surprise; but the manganese concretions in the ferruginous sand below are still more extraordinary. Here the most beautiful botryoidal masses of the black oxide are common and of great variety in form. One of these has a length of five inches and its specific gravity exceeds that of the manganese nodules which are figured in the description of the voyage of the "Challenger." In other respects there is a general resemblance, the chief difference being that in this case ordinary quartzose sand functions as the material caught up by the mineral instead of fine pumice and volcanic fragments, as is the case of those found at the bottom of the Pacific.

A word as to the nature and fossil contents of the Creechbarrow limestone must conclude the descriptive part of this notice. There are considerable varieties, ranging from a soft, marly deposit, which soils the fingers like whitening, to a hard compact rock, which takes a good polish. The more compact and denser limestones, which prevail near the summit, may be roughly divided into non-pisolitic and pisolitic rocks. The latter are in some cases so peculiar as to call for special notice. There are, for instance, certain enigmatical bodies which, though obviously concretionary, were very puzzling in section, having more or less the shape of a horse-shoe. At last, by good luck, we stumbled on a still more curious body, which is perhaps the most perfect pisolite ever discovered. In this case we perceive a pisolitic concretion with an interior like a very small egg, of which the shell, represented by the concentric layers of brown calcite, is developed so obliquely that it is quite thick on one side and quite thin on the other side. This specimen has been broken in such a fortunate manner that we recognised our horse-shoe section at once with the (included) matrix in the form of an egg projecting from the unequally developed circle.

The difficulty of identifying the fossil shells is greatly increased by concretionary incrustation, but there is good reason for stating that species closely resembling *Paludina lenta* and *Melanopsis brevis* are far from uncommon in the tufaceous limestone of the summit pit, which limestone exhibits no trace of bedding.

The above is a brief account of the facts observed whilst investigating the beds which constitute the upper 250 ft. of Creechbarrow Hill. These beds are totally different from the Bagshot pipeclays and sands by which they are partially surrounded, nor is it by any means certain what their stratigraphical relationship to the Bagshot Beds may be. Where one series begins and the other ends it is as yet (1908) impossible to say, although the writer has had the assistance of Mr. Leonard Pike, whenever boring for pipeclay seemed to throw any light on this obscure subject. The palæontology, so far as it goes, and also the presence of the "egg-like body," are rather in favour of the limestone being of Bembridge age; but are there any beds associated with the Bembridge Limestone analogous to those containing the big flints, to the local accumulations of flint gravel, or to the strange manganese sands, all of which are, in one place or another, associated with the Creechbarrow Limestone?*

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* For further details see "Creechbarrow: An Essay in Purbeck Geology," by W. H. Hudleston, *Proc. Dorset Nat. Hist. and Antiquarian F.C.*, vol. xxiii (1902), p. 146; and *Geol. Mag.*, dec. 4, vol. ix (1902), p. 241; and vol. x (1903), pp. 149 and 197. [Since this chapter has been in print a paper has appeared by Mr. H. Keeping in which he states that in his opinion there is no doubt of the Bembridge age of the Creechbarrow Limestone. *Geol. Mag.*, dec. 5, vol. vi (1909), p. 555.]

CHAPTER XVII.

THE DORSET COAST.

By HORACE WOOLLASTON MONCKTON, F.L.S., F.G.S.

THE coast of Dorset has been frequently visited by the Association, sometimes at Whitsuntide but more often at Easter, the genial climate making it especially suitable for a geological excursion early in the year.

The geology of the coast line is of great interest and exhibits an extraordinary variety of highly fossiliferous formations. The shore is for the most part formed of rocks belonging to the Jurassic Series, but near Lyme Regis, at Lulworth, and near Studland the overlying Cretaceous beds appear in the cliffs, and in the eastern end of the coast section, between Studland and Bournemouth, the shore-line cuts into sands and clays of the Eocene. We propose to begin our record of the work of the Association on the Jurassic Rocks at the western end of the county, and to go eastwards, dealing with them as far as Swanage; then to double back and say a little about the Cretaceous formations, and finally to pass on to the Eocene. In order to complete our note of two of the excursions it will be necessary slightly to overstep the county boundary and to trespass on Devonshire.

JURASSIC.

Lyme Regis.

Lyme Regis was first visited by the Association at Easter, 1889,* but as long ago as the 1st June, 1871, a party of our members, led by Professor Buckman and Mr. Logan Lobley, had approached very close to it.† Mr. Lobley reports that "The fourth day was devoted to an examination of the fine coast section extending eastwards from Seaton in Devonshire. The Keuper Marls are here seen forming richly-coloured, picturesque cliffs of a hundred feet in height, which stretch along the shore from the mouth of the Axe for upwards of a mile, when Liassic strata begin to appear and afterwards form, with a capping of Upper Greensand, the cliff until the famous landslip is reached."‡

This part of the cliff section was again visited on April 17th,

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* *Proc. Geol. Assoc.*, vol. xi, p. xxvi.

† *Proc. Geol. Assoc.*, vol. ii, p. 250.

‡ The late Mr. Hudleston informed me that during the early summer of 1869, Prof. Morris led a party of excursionists, some of whom were members of the Association, to Lyme Regis, from which place they on one day visited the famous landslip, and on the next day walked along the shore coast to Bridport Harbour, picking up many interesting fossils on the way.

1906,* when the report states: "The party then descended by Charton Goyle to Charton Bay, where a fine section was seen of the Grey Marls that occur beneath the Black Rhætic Shales and above the red and variegated Keuper Marls. These Grey Marls have formed a debatable ground between Rhætic and Keuper, and they may appropriately be regarded as passage-beds.

"Attempts to find the Bone-bed *in sitû* were not successful owing to slips, but some slabs with fish remains were picked up."

On the 15th April, 1906, a visit was paid to the Yawl lime-kilns near Uplyme, where the lower beds of the Lower Lias zone of *A. planorbis* and part of that of *A. angulatus* were exposed with the White Lias (Rhætic) below. A few fossils were obtained, including *A. conybearei*, *Pleuromya* sp., and *Ostrea liassica.*†

The junction of the Rhætic and the Lias is again well seen at Pinhay Bay. (See Plate XII, Fig. 1.)

We quote mainly from the report of the excursion of 1889.‡ "Proceeding along a tortuous path, amid fallen masses of Chalk and Greensand, the members arrived at the Pinhay Ravine, and after a rough and somewhat muddy descent by the watercourse, reached the shore. The ravine itself coincides with a fault that throws down the limestones of the Lower Lias some feet on the west. Eastwards there appears the White Lias, dipping in the same direction, and covered by a thick mass of Blue Lias limestones.

"The full thickness of the White Lias is about twenty-five feet, but the base is not here seen.

"The rock is remarkable for containing many 'pebble-like concretions,' which stand out in relief on its weathered faces. These lumps are composed of hard white or pale grey limestone, very similar to the matrix, and the following explanation has been suggested by Sir Archibald Geikie, when on a visit to the coast in 1885: the calcareous mud may, during the accumulation of the strata, have been from time to time exposed to the sun's rays, so that films of mud might have curled up, and these, if subsequently rolled by an incoming tide, would be shaped into the lumps which form so conspicuous a feature in the rock.

"Fossils are not readily obtained here, but they may be procured from exposures farther west."

On the 1906 excursion "the members were fortunate in finding some good exposures of the black *Avicula-contorta* Shales on the foreshore, and examples of *A. contorta*, *Cardium rhæticum*, and *Pecten valoniensis* were obtained. The Cotham Marble was not exposed, owing, no doubt, to coverings of beach, shingle and

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* *Proc. Geol. Assoc.*, vol. xix, p. 338.

† *Proc. Geol. Assoc.*, vol. xix, p. 332.

‡ *Proc. Geol. Assoc.*, vol. xi, p. xxx.

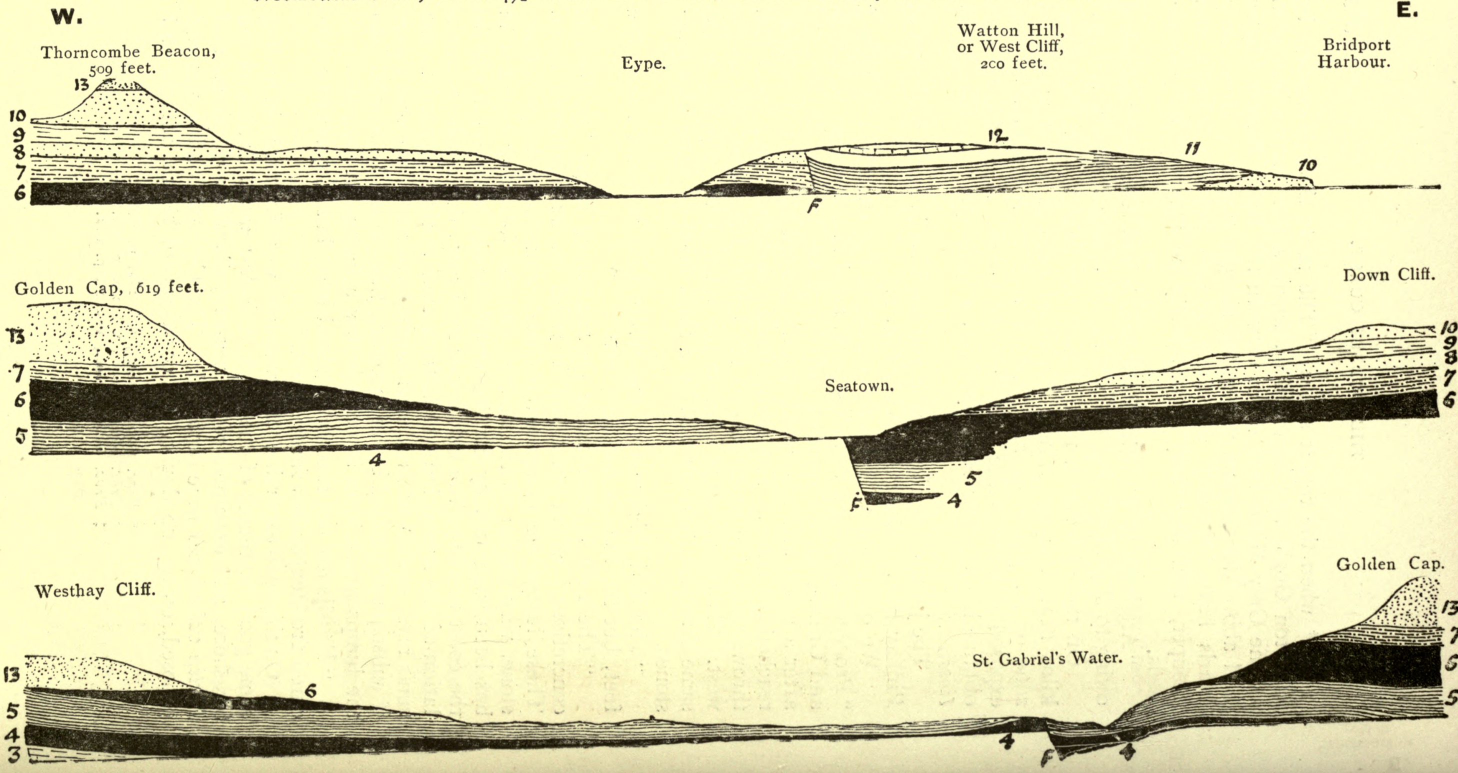
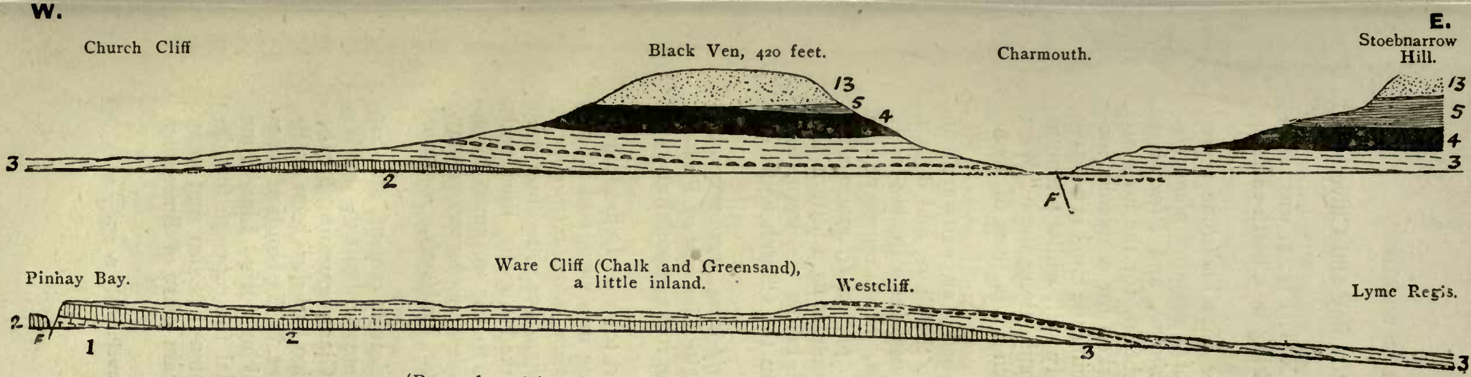


Fig. 61.—Section of the Cliffs from Pinhay Bay, near Lyme Regis, to Bridport Harbour.—*H. B. Woodward.*
Horizontal Scale, about 4½ inches to a mile. Vertical Scale, an inch to 800 feet.



(Reproduced by permission of the Controller of H.M. Stationery Office.)

F.	Faults.		
13.	Chert Gravel, Upper Greensand, and Gault.		
12.	Forest Marble.	Shales with band of limestone. Fossil-Bed (Bradford Clay) at base.	
11.	Fuller's Earth.	Grey Marl with bands of earthy limestone.	
10.	Midford Sands.	Sands with bands and concretionary masses of calcareous sandstone ...	Zones of *Ammonites opalinus* and *A. jurensis*.
9.	Upper Lias	Clays and sandy shales (passing into beds above); thin limestone at base ...	Zones of *Ammonites jurensis*, *A communis*, and *A. serpentinus*.
8.	Middle Lias.	Marlstone (thin layer) ... Sands with concretionary masses of calcareous sandstone ...	Zone of *Ammonites spinatus*.
7.		Laminated-Beds.—Sands, shales, and flaggy sandstone; Starfish-Bed at base ...	Zone of *Ammonites margaritatus*.
6.		Blue Clays.—Three tiers (stone-beds) at base ...	
5.	Lower Lias.	Green-Ammonite-Beds.—Clays with *Ammonites latæcosta* ...	Zone of *Ammonites capricornus*.
4.		Belemnite-Beds.—Pale-grey Marls, etc. ...	Zones of *Ammonites jamesoni* and *A. armatus*.
3.		Black Marl.—Dark shales ...	Zones of *Ammonites raricostatus*, *A. oxynotus*, and *A. obtusus*.
2.		Blue Lias.—Limestone and shales ...	Zones of *Ammonites turneri*, *A. bucklandi*, *A angulatus*, and *A. planorbis*.
1.		Rhætic-Beds.—White Lias.	

boulders. It had been observed at Charton Bay and Culverhole near Axmouth."*

The photograph reproduced as Plate XII, Fig. 1, was taken from the shore near Pinhay Ravine, looking in a north-easterly direction towards Lyme Regis.

Above the Rhætic we see the Lower Lias limestone representing the "Ostrea-beds," and the zone of *Ammonites planorbis*. These yield *Ostrea liassica*, *Modiola minima*, and *Pleuromya crocombeia*, but fossils are not easy to obtain, for the beds are not very accessible, and are not here worked for economic purposes. "Moreover, the geologist in examining the cliffs is not free from danger, as pieces of rock occasionally fall, whilst attention must be paid to the state of the tide, both along these 'West Cliffs' and at those known as the 'Church Cliffs' east of Lyme Regis.

"The *Planorbis*-beds are not exposed far eastward of Pinhay Bay, for they gradually descend to the shore, and do not rise again with the higher beds of limestones above the sea-level. The mass of the limestones, or 'Blue Lias,' which represent also the zones of *Ammonites angulatus* and *A. bucklandi*, attain altogether a thickness of about eighty feet, undulating a little in the West Cliff, descending to the sea-level below the town, and rising again (except the *Planorbis*-beds) in the Church Cliffs on the east.

"Spines of urchins, *Cidaris* and *Hemipedina*, were noted by Thomas Wright in the clays above the White Lias east of Pinhay Bay, but they were only to be seen on the rocks exposed at low-water during spring tides.

"Proceeding eastwards along the coast towards Lyme Regis, higher and higher beds of limestone come into view, and layers containing *Rhynchonella calcicosta*, *Gryphæa arcuata (incurva)*, and one or two specimens of *Ammonites angulatus* were observed. Farther on the stone is extensively worked for the lime and cement works, and each layer is known to the workmen by a particular name. Fine specimens of *Ammonites charmassei* may sometimes be obtained, also *Ammonites bucklandi*, *Nautilus striatus*, *Lima gigantea*, etc.

"Lyme Regis is celebrated for its hydraulic cement, and Sir H. T. De la Beche remarks that when Smeaton built the Eddystone Lighthouse he sent to Aberthaw, in Glamorganshire, for the Lias lime, whereas, if geological knowledge had then been available, he might have procured it from Dorset.† The bands of limestone are employed at the kilns for making 'Blue Lias' lime and hydraulic cement, furnishing material for concrete foundations, brickwork, stucco, etc. Much material is also sent away at times in the raw state. Above the main mass of limestones there are also some layers of 'Cement-stone,' whose composition is best suited for the preparation of cement."*

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* *Proc. Geol. Assoc.*, vol. xix, p. 337.

† "Report on the Geology of Cornwall, etc.," p. 507.

The Cobb at Lyme Regis is built of Cow stones from the Upper Greensand with a walling of Portland roach.

At the "Church Cliffs," to the east of Lyme Regis, the waste of the coast by marine action is very apparent, and the churchyard itself has been somewhat curtailed. It was mentioned on the 1906 excursion that remains of valley drift with Mammoth and Rhinoceros had existed on the lower part of the Church Cliffs at the beginning of the last century, this having been, no doubt, a portion of the old valley of the Char, now obliterated by the encroachment of the sea.

The platform of limestone-rock, exposed at low tide, is a plain of marine erosion, and to the east of the Church Cliffs, where the general dip of the limestone strata is easterly, the bay has been excavated in the softer overlying clays and shales.

The hand of man has, however, grievously aided in the destruction of the coast by quarrying the limestone and by tearing up reefs and ledges on the foreshore, a process, as was remarked in 1906, which has not been altogether abandoned.

The cliffs on both sides of Lyme Regis are formed of Lower Lias, and a full statement of the details of the formation will be found in the Memoir by Messrs. Woodward and Ussher.†

The limestone series of the "Church Cliffs" includes the zones of *Ammonites angulatus*, at the bottom of the cliff, of *A. bucklandi*, and of *A. semicostatus* (with *A. turneri)*, the upper limit being taken at the Hard Marl or Table Ledge, a conspicuous band, a little above the main mass of limestones, which descends to the sea shore at the foot of Black Ven.

The Director remarked, 1906, that many who come to Lyme Regis for a short time are apt to be disappointed at not easily finding *in sitû* fine examples of fossils. Such were not to be obtained readily, except perhaps in the cottage of Isaac Hunter‡ at Charmouth. Time and labour were needed in this, as in most other famous localities for fossils, and many of the better specimens have been obtained from fallen blocks. It was hoped that the particulars of the strata given in the Survey Memoir might prove a basis for further detailed work, of which there was much to be done. We knew little of the precise zones of the fishes, and the same might be said of the plant remains, although, as remarked by Professor A. C. Seward, the majority of the British Liassic plants had been obtained from the Lower Lias of Lyme Regis.§

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* *Proc. Geol. Assoc.*, vol. xi. pp. xxx, xxxi.

† The Geology of the Country near Sidmouth and Lyme Regis." *Mem. Geol. Survey*, 1906. pp. 33-37.

‡ This well-known fossil collector died in 1907.

§ Catalogue of the Mesozoic Plants in Dept. Geol. Brit. Mus.: "The Jurassic Flora," II, 1904.

At Black Ven, the Table Ledge, which forms the top of the zones of *A. semicostatus*, having reached the shore level, the lower part of the cliff consists of dark shales, with several bands of cement stone and an occasional thin limestone. These form the Zones of *A. obstusus*, *A. oxynotus*, and *A.raricostatus*, and are about 190 feet in thickness. The metal-bed in this series contains much pyrites, and its decomposition has been known to give rise to the spontaneous combustion of the bituminous shales. An instance occurred during the winter of 1907-8 in the cliffs between Lyme Regis and Black Ven, and the phenomenon was announced in a local paper as a "Volcanic Eruption."

Above the shales we find a well-marked band of pale grey marl with indurated bands of pale marly limestone, with a thickness of some eighty feet. It is known as the "Belemnite Beds," and represent the zones of *A. jamesoni* and *A. armatus*. These beds yield Belemnites in abundance, but are not otherwise very fossiliferous, except towards the upper part.

There is a trace of the "Green Ammonite Beds" at the eastern end of Black Ven, but they are better seen farther to the east. The top of the hill is composed of Cretaceous strata, to which we will return later on.

The valley at Charmouth coincides with a fault which, though of no great magnitude, somewhat assists the easterly dip and brings the Belemnite beds gradually down to sea level, and they may be satisfactorily studied and the fossils collected in Stonebarrow Cliff and Westhay Cliff.

The overlying Green Ammonite beds, zones of *A. henleyi* and *A. capricornus*, are also well shown in Stonebarrow Cliff, and continue in the cliff section to Golden Cap, and as far as Seatown, where a fault carries them below the sea level. These beds consist of a series of bluish-grey, micaceous marly clays, with occasional indurated bands, nodules of hard grey limestone and ferruginous layers, altogether about 105 feet thick. Towards the lower part of the series the limestone nodules are most abundant, and frequently contain specimens of *Ammonites latæcosta*, which, when cut and polished, are sold under the name of "Green Ammonites," because the spar filling the chambers is often of a green colour.*

Fragments of this Ammonite were found to be fairly abundant, but the Director said that good specimens were rather uncommon.

Resting upon the Green Ammonite Beds is the Middle Lias, its base being marked by the thick bands of calcareous sandstone, known as the "Three Tiers." They are well shown in the great cliff of Golden Cap.

The tiers are each from 2 feet to 4½ feet in thickness, and are separated by 10 to 12 feet of micaceous sandy clay, containing concretionary masses of calcareous sandstone. The entire thickness of these strata varies from 30 to 40 feet.

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* "Geol. of Sidmouth and Lyme Regis" *Mem. Geol. Survey* (1906), p. 30.

Above the Three Tiers we have a considerable thickness of blue micaceous marls, containing ironstone-nodules, iron-pyrites, and small, irregular limestone nodules. There is a conspicuous nodular bed some 95-100 feet above the Three Tiers, which contains *Pentacrinus*, *Belemnites*, and *Lucina*. Above it are about 60 feet of micaceous marls, with occasional bands and nodules of grey earthy limestone, and then we come to the "Starfish Bed," a band of calcareous sandstone. Some sandy beds come next, and complete the Lias Series, shown at Golden Cap, the summit being formed of light-coloured Cretaceous (Selbornian) Beds, which give the Cap its name of Golden. All the Middle Lias here is a part of the *A. margaritatus* zone.*

BRIDPORT

Bridport has been twice visited by the Association, viz., at Whitsuntide, 1885, and at Easter, 1898. The former excursion followed a day at Sherborne under the direction of Mr. W. H. Hudleston, while the coast visit was conducted by Mr. H. B. Woodward. The Directors in 1898 were the Rev. J. F. Blake and Mr. S. S. Buckman, and the Report is by the Directors and H. W. Monckton.†

Down Cliffs were visited during the Lyme Regis Excursion of 1889, the Director being Mr. H. B. Woodward, and the Report being by him.‡

We make use in the following of all these Reports.

At Down Cliffs, east of Seatown, there is a fine exposure of the Middle and Upper Lias beds, though the latter are not easy of access.

The bottom of the cliff is formed of the clayey beds containing *A. margaritatus*, which we saw above the Three Tiers at Golden Cap. Above them there is the layer of hard, greenish-grey micaceous and calcareous sandstone which is known as the Starfish Bed. It is 4½ ft. thick, and large blocks from it may be seen on the slopes of the cliff, or on the shore between Seatown and Eype, and where the smooth lower surface of the bed lies uppermost and can be examined, many oblong or square holes will be seen marking the places from which the starfishes have been chiselled by collectors. Two species are recorded from this bed, *Ophioderma egertoni* and *O. tenuibrachiata*.§

Above the Starfish Bed come the laminated beds, a series of micaceous and ferruginous sandy clays and marls, having in places a banded appearance. These are surmounted by more distinctly laminated micaceous sands and clays, with bands of hard micaceous and flaggy sandstone, which exhibit current-bedding, and occûr in isolated masses. Between these last-mentioned beds there is a hard, sandy limestone containing *Pentacrinus gracilis* and starfish, or fragments thereof. It is about 100 ft. up in Down Cliff, 130 ft. up under Thorncombe Beaçon, and is also seen in Eype Cliff. All these beds belong to the zone of *A. margaritatus*, and the top of the zone is about 90 ft. above the Starfish Bed.*

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* Much of the above is taken from H. B. Woodward, *Mem. Geol. Survey*, "Jurassic Rocks of Britain," vol. iii, pp. 195-197.

† *Proc. Geol. Assoc.*, vol. ix, 1885, p. 200, and vol. xv, 1898, p. 293.

‡ *Proc. Geol. Assoc.*, vol. xi, 1889, p. xxxix.

§ *Mem. Geol. Survey*, "Jurassic Rocks of Britain," vol. iii, p. 197

The base of the zone of *A. spinatus* is formed by the "Margaritatus Stone" of Mr. E. C. H. Day.† It is a hard blue and reddish-brown ferruginous sandy limestone fissile at the base, some 200 ft. up in Down Cliff. It forms a conspicuous red band about one foot in thickness, and amongst the fossils most easily to be obtained are *Belemnites* sp., *Gryphæa cymbium*, *Lima* sp., *Pecten æquivalvis*, *Spiriferina pinguis*, and *Rhynchonella serrata*.

Above this bed there is a band of pale bluish-brown or light grey clay from 6 to 20 ft. thick; this is overlain by the Yellow Sands, the downwash from which in some places obscures this otherwise conspicuous band.

The Yellow Sands are often cemented into a hard rock in bands with ferruginous joints, and in the form of huge, round concretionary masses or Doggers, of which many examples are to be seen on the foreshore. These sands vary from 40 to 55 ft. in thickness, and extend throughout the Down and Thorncombe cliffs. Above them there is another band of grey, marly, and sandy clay, 10 to 15 ft. thick, extending to the rock-bed at the top of the Middle Lias.

This rock-bed is described by Mr. Woodward as "made up of two layers, the upper of which consists of compact pale pink, yellow, or cream-coloured limestone with irregular surface; it is much iron-stained in places, and from 1 ft. 4 in. to 2 ft. 6 in. in thickness"; from this portion he records *Ammonites bifrons*, *A. serpentinus*, *A. striatulus*, and *Belemnites*.

"The lower layer is a bed of brown, grey, and greenish-grey iron-shot limestone, with nodules about eight inches in thickness; it contains *Rhynchonella acuta*, *Belemnites compressus*, etc. A marked ferruginous seam divides these layers, and aids the splitting up of the rock."

He adds that Mr. Etheridge in 1861 detected Upper Lias fossils in the upper part of this band of rock, and a short time later Mr. Day discovered Middle Lias fossils in the lower portion of the bed.‡ Above this junction bed there are some 70 ft. of blue micaceous marly and sandy shale, which merge upwards into the Midford or Bridport sands. These blue shales are called Upper Lias by the Geological Survey, and assigned to the zones of *Ammonites serpentinus, A. communis,* and *A jurensis* in part. Mr. Buckman does not, however, agree with this classification, and a discussion arose on the 1898 excursion, of which a fairly full Report will be found in the PROCEEDINGS.*

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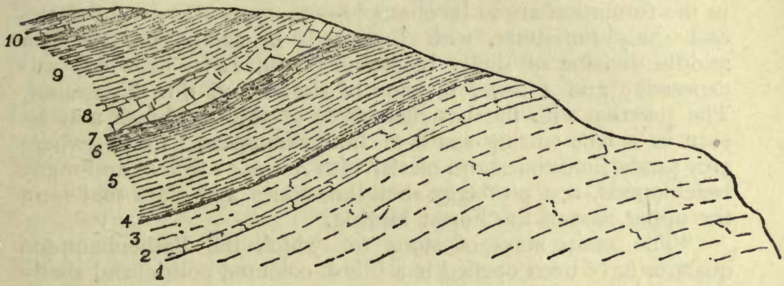
* *Op. cit.*, p. 198.

† *Quart. Journ. Geol. Soc.* (1863), vol. xix, p. 284.

‡ *Mem. Geol. Survey*, "Jurassic Rocks of Britain," vol. iii, p. 199.

At Eype a fault brings newer beds into the cliff section. They belong to the Great Oolite series, or Bathonian, and are divided here into a lower bed of pale bluish-grey marly clay, with many nodules and occasional bands of grey, earthy limestone with a total thickness of about 100 ft., which is assigned to the Fullonian, † and an upper bed assigned to the Forest Marble, as is shown in the illustration (Fig. 62).

FIG. 62.—SECTION AT WEST CLIFF, BRIDPORT.—*H. B. Woodward.*



1—3. Fullonian. 4—10. Forest Marble-Series with *Rhynchonella*-Bed (4) at base, and central mass of limestone (8).

(Reproduced by permission of the Controller of H.M. Stationery Office.)

At the base of the Forest Marble is a fossil-bed, containing *Rhynchonella boueti, R. varians,* and other fossils, occupying the same position as a fossil-bed at Herbyleigh, near Langton Herring,‡ where *Terebratula coarctata* has been found. This layer may represent the Bradford clay of Wiltshire.§

To the east of Bridport Harbour the Midford or Bridport sand is admirably shown in the cliff. It consists of yellow sands with many layers of calcareous sandstone. The sandstone layers weather out on the cliff, giving it a most peculiar banded appearance. These sands, at least in this upper part, belong to the zone of *Ammonites opalinus.*

On the 1898 excursion a visit was paid to a small quarry not far from the cliff to the east of Bridport Harbour. The rock belongs to the *Parkinsoni*-zone—that is, it is near the top of the Inferior Oolite, and a considerable number of fossils were obtained by members of the party.

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* *Proc. Geol. Assoc.,* vol. xv, pp. 293-296.

† H. B. Woodward, *Mem. Geol. Survey,* "The Jurassic Rocks of Britain," vol iv, pp. 233, 343.

‡ See *ante,* p. 353, and *post,* p. 395.

§ See Correlation Table by L. Richardson, *ante,* p. 351.

The overlying Fullonian clay is seen in the cliffs, and has already been alluded to. Above it we find the Forest Marble, which is to be seen in West Cliff and at the Bothenhampton quarries. We quote from the report of the 1885 excursion:*

"Passing through Bothenhampton, the members proceeded to the quarries in the Forest Marble, situated to the south of the village. Here this formation is seen dipping to the northwards, towards the Middle Lias, against which it is faulted. The fault is no doubt a continuation of the disturbance which brings the same foundations in abrupt contact to the east of Eype Mouth, where the downthrow must be at least 425 ft. The hillside south of Bothenhampton is scarred with old pits from which the Forest Marble has been raised for many years past, the stone having been worked on a dip-slope. Here three main divisions in the formation are to be observed—an upper division of shales and shaly limestone, with thin beds of shelly limestone; a middle division of shelly limestone (about 12 ft. of which was exposed); and a lower division of shales and thin limestones. The junction with the basement beds of the Cornbrash may be seen in a lane-cutting south of Bothenhampton Church, where grey sandy limestones and marls, with *Avicula echinata* and many brachiopods, rest on flaggy shell-limestones and clays that form the upper part of the Forest Marble.

"The main mass of stone for which the Bothenhampton quarries have been opened is a bluish-coloured oolitic and shelly limestone, very much false-bedded. This rock, known as 'B'ampton Stone,' is used for building purposes and for road-mending, and slabs are obtained for piggeries and for stiles. It is too much impregnated with ocherous galls to be useful as marble. Prof. A. H. Church is of opinion that iron-pyrites has originally been the colouring material of the blue bands of the Forest Marble, and that the yellowish-brown exterior is due to the oxidation of the pyrites.†

"Among the fossils to be observed in the stone are *Pecten lens*, *P. vagans*, *Lima duplicata*, *L. cardiiformis*, *Ostrea sowerbyi*, *Cyprina loweana*, and *Apiocrinus parkinsoni*. Joints of the last-named fossil, termed 'Coach-wheels,' are not uncommon. Some reptilian bones have also been obtained, as well as fragments of lignite. Curious markings are abundant on some of the surfaces of the sandy limestone-shales, and they appear to be tracks of invertebrate animals. It was pointed out that the Great Oolite developed near Bath and for some distance to the south of that city does not occur so far south as Dorset, being represented perhaps in part by the Forest Marble and in part by the Fuller's-Earth."

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* *Proc. Geol. Assoc.*, vol. ix, p. 201.

† *Quart. Journ. Chem. Soc.*, Series 2, vol. ii, p. 379.

WEYMOUTH.

The Association has paid three visits to Weymouth, viz., at Easter, 1879, at Easter, 1889, and at Easter, 1898. Portland was visited during the second of these excursions, and we quote from the Report by W. H. Hudleston :* "The party, after crossing the ferry, made for the summit of the Nothe ridge, where the Director briefly indicated the plan for the day. It was proposed to spend a couple of hours in examining the Corallian series from the Nothe to Sandsfoot. Here the beds, dipping towards the south at a moderate angle, and quite free from dislocation, afford an excellent opportunity for studying the sequence. The series is estimated at 230 ft.; the two Lower Grits and intervening clay being more than twice as thick as the corresponding part of the series at Osmington, whilst the equivalents of the Osmington Oolites suffer a corresponding diminution. The *Trigonia*-bed series, or Main Corallian Limestone, affords a rough, though nearly level, platform for several hundred yards (dip 8.5°) in the little bay between Bencliff Point and Sandsfoot Castle. Above this platform succeed what may be termed the Upper Corallian beds, commencing with the Sandsfoot Clay and continued by the Sandsfoot Grits, with occasional clays. There was no time to take more than a passing look at these, but the Director pointed out the sudden and immediate change from the Corallian Limestones (represented in other districts by Coral Rag and Coralline Oolite) to clays which were in some respects Kimeridgian in character, these being succeeded by red grits full of large Monomyaria and with a tendency to ferrugination in their upper parts. The Abbotsbury Ironstone is probably on the horizon of the clays and sandy beds of the upper part of the Sandsfoot Grits, and may be regarded as on the borders of the Corallian and Kimeridge.

"The party now doubled back towards Weymouth, and after inspecting the Rodwell cutting took train for Portland. Here they were joined by Mr. Wallis, who acted very efficiently as local guide. The slope of the escarpment on the west side of the Vern Fort was ascended to a point where a new incline had been constructed, leading to the Admiralty quarries on the plateau. No better section of Portland Stone, or one more easily examined, has ever been made. The cutting of the incline commences at the top of the indurated Portland Sand, and displays several feet of Portland Clay, though this deposit is said to be variable in thickness.† As is well known, the Portland Stone of the island is divisible into two portions—the

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* *Proc. Geol. Assoc.*, vol. xi. p. liv.

† This clay is represented in the section appended to Mr. W. Gray's paper "On the Geology of the Isle of Portland," *Proc. Geol. Assoc.* (vol. i, p. 132), and is recorded by Prof. Blake in the "Portland Rocks of England" (*Quart. Journ. Geol. Soc.*, vol. xxxvi, p. 192).

Lower or Cherty series and the Upper or Building-Stone series. The lower series is a sort of impure Chalk full of brown and black chert, which possesses no economic value beyond that of filling up a hole where necessary, but there are several lines of fossils. Each of these can be examined inch by inch, and thus a fine opportunity must have been afforded to obtain the numerous varieties of *Trigonia gibbosa,* for beautiful specimens of which this rock is so remarkable. The Building-Stone series here consists of two thick beds of freestone *(Base bed* and *Whit bed),* separated by a coarse fossiliferous and flinty series, part of which is termed the 'Curf.' The 'Roach,' which terminates the Portland Stone upwards, contains a fine and varied series of fossils, which on the whole are of a very different character to those of the Cherty series. Numerous minute Gasteropoda, often associated with small Conchifera and triradiate sponge-spicules, the shells chalcedonized, characterise the topmost layer of the Roach.

"The party were next conducted through the Vern ditch to the east side of the island, where an interesting view can be obtained looking down upon the Breakwater, and an advance was made for a short time in the direction of the convict prison. Ultimately, having now gained the summit of the plateau, the party proceeded to inspect some of the private building-stone quarries, where the various phenomena in connection with the Roach, the Lower Dirt-bed, the Skull Cap, and the Main Dirt-bed with its 'Burr' Trees were observed and duly discussed. Although there is not much left of the Lower Purbecks on Portland Island, doubtless that little is of extreme interest. A novel feature in connection with the calcareous rings which environ the 'Burr' Trees was mentioned by Mr. H. B. Woodward. A tree occurring horizontally in the Dirt-bed at Portisham had a calcareous envelope of such large dimensions and singular shape that it was pronounced by the local authorities to be a fossil elephant, and people were invited from far and near to inspect it.

"The topmost group of the Purbecks on Portland Isle consists of a kind of calcareous slate, often bearing the marks of much disturbance. A few years ago some excavations were discovered in these slates which attracted the attention of Mr. Wallis, who, fortunately, bethought himself of applying to the Association for assistance in interpreting the discoveries. The result was the very interesting paper 'On Some Curious Excavations in the Isle of Portland,' by Mr. T. V. Holmes.* Up to 1884 from twelve to fourteen beehive-shaped holes had been discovered. The author points out the affinities between these 'Portland Pits' and the ordinary Kent and Essex Dene-holes. The holes appear to have been used as granaries."†

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* *Proc. Geol. Assoc.*, vol. viii, p. 404, *et seq.*

† See *ante*, pp. 59 and 240.

On April 11th, 1898, the district to the west of Weymouth was explored. A few of the members crossed the Backwater to the opposite shore and were able to pick up several Ammonites of the *Cordatus* group representing the upper part of the Oxfordian. The main party walked along by the side of the railway to the north end of the Backwater and examined the section in the Cornbrash, which is figured in the "Jurassic Rocks of Britain."*

The rubbly character of the rock was noted, indicating that the Cornbrash is a basal deposit. Numerous examples of *Macrocephalites* were obtained, and one example which would probably be recorded as *A. discus*, but which Prof. Blake thought more likely to be the *A. hochstetteri* of Oppel recorded by him from the Cornbrash of Chippenham.

He drew attention to the fact that on the Continent the zone of *A. macrocephalus* is usually united with the Oxfordian, and that the indications here were that it ought to be so classed. In support of this he pointed to the variable character of the underlying Forest Marble in this district, and in the course of the day it was shown to be argillaceous at Radipole, sandy and concretionary at the top of the hill to the south, and shelly at Langton Herring, but always followed by the same kind of rubbly Cornbrash recognisable by *Avicula echinata*. The existence of a break below the Cornbrash is thus shown, whilst the gradual intercalation of clays and the similarity of the fauna indicate an absence of any break above it.

A fine section in the Oxford Clay at Chickerel brickyards enabled the members to collect fossils from the *A. ornatus* zone, and the walk was continued to Herbyleigh on the shore of the Fleet, where the Brachiopod-bed is exposed. It is a band of earthy marl some two feet thick, forming the base of the Forest Marble Series and representing the horizon of the Bradford Clay of Wiltshire.† *Rhynchonella boueti* and *R. varians* were found to be exceedingly abundant, and specimens of *Terebratula coarctata*, *T. intermedia*, *T. maxillata*, *Waldheimia digona*, and *W. obovata* were obtained by members of the party.

On the shore of the Fleet, to the south of Langton Herring, there is a section in the Fuller's Earth showing a bank composed of *Ostrea acuminata*. It does not appear to have been inspected by the Association, but it is a very interesting example of a fossil oyster bed.

We have already mentioned the Corallian Rocks of the Nothe and Sandsfoot, south of Weymouth, and the series is also well shown on the coast near Osmington; indeed, nowhere in England, south of Yorkshire, are there such fine sections of the Calcareous Grit, Coralline Oolite, and Upper Calcareous Grit.

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* Vol. iv, p. 436, fig. 129.

† See *ante*, pp. 353 and 391, and "Jurassic Rocks of Britain," vol. iv, p. 341.

The Oxford Clay is the lowest formation seen in the Osmington Cliffs. Above it we find the Nothe Grits, Nothe Clay, and Bencliff Grits, then, in ascending order, the Osmington Oolite, with the *Chemnitza* bed in its upper part forming a prominent ridge on the shore. Above the Osmington Oolite are the very interesting Trigonia-beds, with a thickness of 14 feet. They consist of gritty and shelly limestones, forming ledges and pavements on the foreshore with *Trigonia clavellata.* The Trigonia-beds also contain *Ammonites plicatilis,* and many other fossils.

Above the Trigonia-beds come the Sandsfoot Clay, Sandsfoot Grits and the Upper Coral Rag, which ends the Corallian series.* At Ringstead Bay we find at the top of the Corallian a coral bed with *Thecosmilia*, *Thamnastræa*, and many other fossils.

On the 1898 excursion a good deal of attention was paid to the cliff at Holworth House in Ringstead Bay. We quote from the Report: †

"Mr. Hudleston led the way to the cliff near Holworth House, and pointed out a fault which cuts the cliff in a nearly north and south direction. The section on the east side of the fault shows the junction of the Purbeck and Portlandian strata. The Lower Purbeck here is a flaggy limestone with faint traces of a 'dirt bed' in places and with no marine fossils—indeed, few fossils of any kind. The uppermost Portland rock here consists of a kind of 'Roach,' a hard Limestone full of casts of marine shells, *Pecten lamellosus*, Sow.; *Cardium dissimile*, Sow.; *Pleuromya tellina*, Roem.; and varieties of *Trigonia gibbosa*, Sow., were amongst the species found by the members. The absence (or rarity) of *Cerithium* serves to distinguish this bed from the typical 'Roach' of the Isle of Portland. Mr. Hudleston said that this change from marine to freshwater conditions, shown in the section, was evidence of some interval between the Portland and Purbeck series, and, in fact, he was certain that an extensive planing of the Portland rocks had taken place in the interval between the deposition of those two formations. The Purbecks rest upon different portions of the Portland rocks in different parts of the country, here on a representative of the 'Roach,' at Portisham on the flinty series. A similar transgression of Purbecks over various members of the underlying Portlands was also noticeable in the Vale of Wardour.

"On this Professor Blake said he would make a speculative remark. In the South of France there is a series of beds inter-

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* See Blake and Hudleston, "Corallian Rocks of England," *Quart. Journ. Geol. Soc.*, vol. xxxiii (1877), p. 271. Full sections are given in "The Jurassic Rocks of Britain," vol. v, pp. 85-87.

† *Proc. Geol. Assoc.*, vol. xv, p. 302.

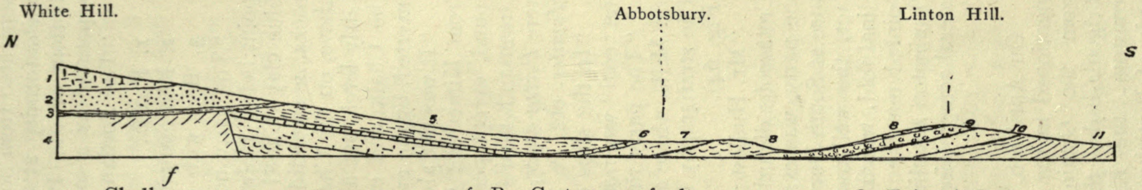

FIG. 63.—SECTION THROUGH LINTON HILL AND ABBOTSBURY.—*After A. Strahan.*

1. Chalk.
2. Upper Greensand.
3. Gault.
4. Forest Marble.

f. Pre-Cretaceous fault.
5. Kimeridge Clay.
6. Abbotsbury Ironstone.
7. Sandsfoot-Beds.

8. *Trigonia*-Beds.
9. Osmington Oolite.
10. Lower Calcareous Grit.
11. Oxford Clay.

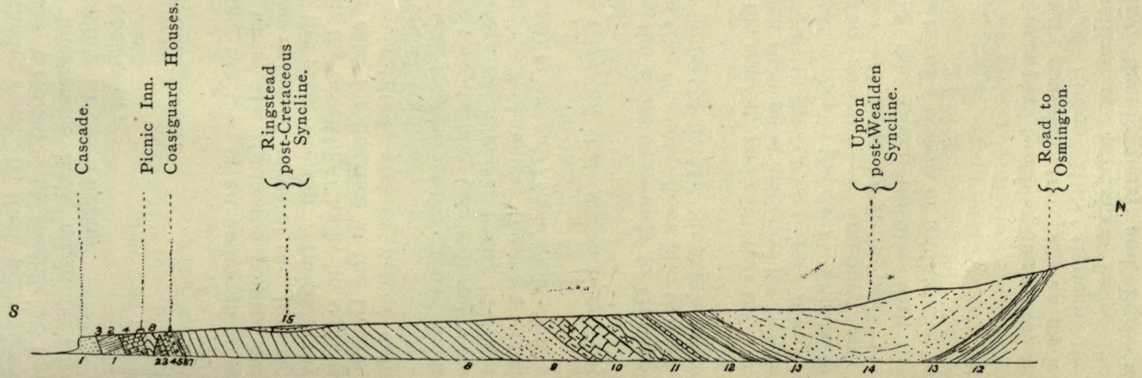

FIG. 64.—SECTION ALONG THE STREAM OF OSMINGTON MILLS.—*A. Strahan.*

1—7. Corallian.
8. Kimeridge Clay.

9—10. Portlandian.
11—13. Purbeckian.

14. Wealden.
15. Upper Greensand.

mediate between the Jurassic and Cretaceous, which are separated from both as the Tithonic stage. If, then, we have an unconformity at the top of the Wealden and another at the bottom of the Purbeck the intervening beds might be also separated as a series corresponding to the Tithonic.

"The Portland Beds seen consist of:

1. Roach.
2. Representative of the building-stone.
3. Beds with chert.

"The party now passed along the face of an undercliff to a point below Holworth House, where Mr. Hudleston pointed out blue clay (Gault) resting on the upturned edges of the Jurassic rocks, a splendid example of the great overlap. Immediately above, on the Chaldon Plateau, the overlying Chalk, he said, is fairly level, but a little farther east, for instance at the Durdle, the Chalk and everything else is tilted, and in places even inverted, by the great Isle of Purbeck fold.

"It was not always an easy task to separate the slipped Gault from Kimeridge Clay, and no very definite Gault forms were found, except perhaps *Inoceramus concentricus*, Park. Upper Greensand fossils were abundant. Amongst those collected were *Pecten asper*, Lam.; *Myacites (Panopœa) mandibula*, Sow.; *Hamites*, etc.

"In the slips of Kimeridge Clay, oil shale was noticed, but the 'coal' was not found *in sitû*.

"The party then walked by the shore westwards to Osmington Mills, where a small stream (the Cascade) flows into the sea. The stratigraphy is sufficiently indicated by Mr. Strahan's figure (Fig. 64).

"Mr. Hudleston explained the section, and said that the pre-Cretaceous disturbance, of which such good evidence lay before the party, was exactly in line with the post-Cretaceous disturbance at South Down Farm studied earlier in the day. This is, in fact, the well-known Osmington anticline—a fractured anticlinal fold, which has tilted the Corallian rocks in the bay. He pointed out the connection of the Upton syncline with the Osmington anticline as being parts of a system of folding due to lateral compression."

ABBOTSBURY.

On April 9th, 1898, a visit was paid to Abbotsbury and, as mentioned in the Report,* a very complete traverse was made from the Osmington Oolite of Linton Hill, through the Trigonia-beds, the supra-coralline or Sandsfoot beds, the ironstone, the Kimeridge Clay, the Portland and Purbeck beds of Portisham Hill. The general succession is shown in Dr. Strahan's section, Fig. 63. In the quarries at Portisham

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* *Proc. Geol. Assoc.*, vol. xv, p. 298.

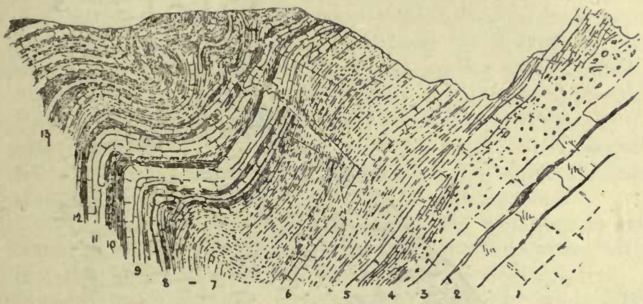
Hill the Purbeck beds were examined, and a band full of *Cyrena* noted.

"The Portland Limestone was found to be here not so fully developed as in the Island of Portland, but immediately over the flinty series—here containing *Ammonites giganteus*—was seen a thin, dark, carbonaceous bed with fragments of wood. On this horizon two large trees were seen, one horizontal, some 6 to 8 feet long, and hollowed out in the middle, the other vertical, with large spreading roots."

The Abbotsbury iron-ore was examined in one of the lane cuttings near the village, and many fossils were obtained. Mr. H. B. Woodward remarks* that "these red lanes are excavated in loose red and brown oolitic iron-ore, with some sand and sandstone and irregular, vertical, and other bands of ironstone, and flaggy oolitic ironstone on top. A thickness of at least twenty feet is shown. The more prevalent fossils include *Ammonites*, *Cardium*, *Myacites*, *Trigonia*, *Chemnitzia*, *Waldheimia*, *Rhynchonella*, and *Serpula; Ostrea deltoidea* and Lignite also occur."

FIG. 65.—DIAGRAM-SECTION OF PART OF STAIR HOLE, LULWORTH, DORSET.—*H. B. Woodward.*

(Reproduced by permission of the Controller of H.M. Stationery Office.)



Beds 9 to 13 Middle Purbeck.
Beds 2 to 8 Lower Purbeck.
Bed 1 Portland Stone.

This iron-ore is in the upper part of the Corallian beds, bordering the Kimeridge Clay, and was of especial interest to those who had been on the excursion of Whitsuntide, 1893, when the Westbury iron-ore, which occurs in a similar geological position, was examined (see page 298).

THE ISLE OF PURBECK.

Durdle Door does not seem to have been inspected by the Association, and Lulworth Cove was only once visited in an unofficial manner during the Swanage Excursion of 1896.†

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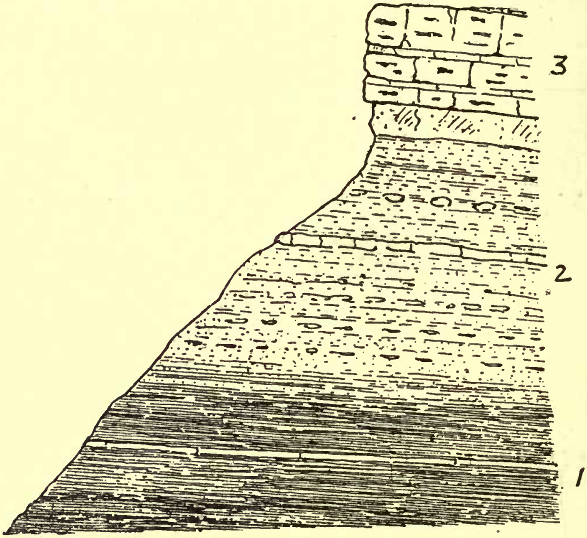
* "Jurassic Rocks of Britain," vol. v, p. 94.

† *Proc. Geol. Assoc.*, vol. xiv, p. 323.

Mr. H. B. Woodward remarks,* "Lulworth Cove has been formed by the erosion of the soft Wealden Beds after the sea had broken through the barrier of Portland Rocks. At Stair Hole, or Cove, there are two or three caves, or tunnels, through the Portland Rocks, the sea perhaps having enlarged fissures in these rocks. Overlying and overhanging masses of Purbeck Caps and Broken Beds occur in places on the eastern side of the barrier that contains these caves."

"The well-known section at Stair Hole shows how much the strata are disturbed. Here the beds are much broken and cemented by veins of calcspar. The shales squeezed up in the central part of the Cove open out towards their outcrop at the edge of the cliff and are in some instances slightly inverted. This is also seen to be the case on the western side of Lulworth Cove." Mr. Woodward's diagrammatic section is reproduced in Fig. 65.

FIG. 66.—SECTION AT GAD CLIFF, ISLE OF PURBECK.
—*H. B. Woodward.*
(Reproduced by permission of the Controller of H.M. Stationery Office.)



3. Upper Portland. Cherty Stone.
2. Lower Portland.
1. Kimeridge Clay.

The Kimeridge Clay is admirably exhibited in the cliffs of the bay of that name, and on the west as far as Gad Cliff, and on the east as far as St. Albans Head. It consists of dark-coloured shales with some layers of cement stone, one of which runs out as a projecting ledge between Kimeridge Bay and Hobarrow Bay, and is known as the Broad Bench. The members assembled upon this ledge during the 1896 excursion, and the director, Mr. Hudleston, made some remarks of which the following is the substance :*

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* "Jurassic Rocks of Britain," vol. v, p. 257.

"There is no point on the whole coast of the Isle of Purbeck where so much is to be seen. It commands the greater part of the enormous development of Kimeridge Clay, with its interesting stratigraphical features on both sides of the anticlinal. Facing the land, you have on the right the whole extent of Kimeridge Bay, terminated on the east by the precipices of Hencliff, where the Upper Kimeridge beds are seen dipping at a moderate angle towards the south-east in the direction of St. Albans Head. The curve of Kimeridge Bay itself is bounded by a low but precipitous cliff, where the hard beds between the softer shales serve to mark the stratigraphy; these hard beds form the Kimeridge ledges, of which a great extent are bare at low spring tides. The general dip in the Bay is to the south-east; but as the west side of the Bay is approached the axis of this local anticline, or '*bombement*,' makes itself felt in a series of faults with downthrow to the south-east, whereby the Bench-rock, on which the party were standing, is repeated several times on the sea-floor.

"On the left, in Hobarrow Bay, the prospect is still more remarkable, for not only are the geological features interesting, but the scenery is of the most impressive character. In the immediate foreground stretches the deep little inlet of Hobarrow Bay, bounded by precipitous cliffs of shale and stone-bands, which mark the Kimeridge beds of this region. At the head of this inlet is the last fault in connection with this upthrust, and here the lowest beds in the Isle of Purbeck are brought to day. Thenceforth there is a steady and rapid dip of all the Kimeridge beds towards the north-west until they pass beneath the Portland Sand at Brandy Bay, which itself is seen to support the mural cliffs of Portland Rock culminating in the noble precipice of Gad Cliff (see Fig. 66)."

Mr. Hudleston then alluded to the peculiarly irregular development of the Kimeridge Clay, than which, as he had often maintained, there is no formation in the whole Jurassic system more difficult to "tabulate or understand."

"This difficulty arises from two principal causes. *Firstly*, the irregularity of the development, which is further increased by a want of definite shell-beds, showing zonal succession, such as characterise the Lias. *Secondly*, from the fact that our Upper Kimeridge is by the French included in their Portlandian, taking Boulogne as the standard. From a French point of view, there are good physical reasons for this, since 'Portlandian' conditions set in earlier at Boulogne than in Dorset. At Boulogne (visited by the Association in 1878*) the volume of the marine Jurassic beds above the Corallian is probably not more than a fourth of the thickness they attain in the Isle of Purbeck, but they are more varied and better furnished with recognisable Mollusca. Argillaceous conditions are much less frequent at Boulogne, and more or less terminate with the shales carrying *Exogyra virgula*, which really represent the top of our Lower Kimeridge, though called by Pellat 'Upper Kimeridgian.' Hence the idea which prevailed for a long time in some quarters that the 'Virgulian' of foreign authors is Upper Kimeridge. The fact is that the 'Virgulian,' or top of the French Kimeridgian, represents the upper part of our Lower Kimeridge.

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* *Proc. Geol. Assoc.*, vol. xiv, p. 314.

"What, then, at Boulogne succeeds the Virgulian horizon? Undoubtedly the Lower Portlandian of the French, where arenaceous and even conglomeratic deposits, with a fauna partly modified by the peculiar physical conditions, occur on the horizon of the lower part of our Upper Kimeridge Clay, as developed in the Isle of Purbeck. These beds constitute the Bolonian of Blake. To understand, then, the correlation of our Kimeridge section, we must bear in mind that the Lower Portlandian of the French (Blake's Bolonian) is on the horizon of the *lower part* of our Upper Kimeridge, whilst the Virgulian of the French corresponds, in the main, with the *upper part* of our Lower Kimeridge.

"It would be necessary, on the present occasion, to apply the preceding generalisations to the study of the local details, as afforded by the grand sections on the Kimeridge coast. There were three principal points for the consideration of the party.

"1. Where to draw the line between the Upper and Lower Kimeridge.

"2. To institute a comparison between the beds on the south-east and north-west sides of the Kimeridge Bay anticlinal.

"3. To observe the local stratigraphy, especially the faults.

"1. *Line between Upper and Lower Kimeridge.*—Owing to the fact of lithological passage and a certain overlap of fauna, the actual line is very difficult to draw. From the base at Hen Cliff to the top of the Kimeridge Clay at Chapman's Pool, there are 650 ft. of beds. At least 580 ft. of these there can be no hesitation in assigning to the Upper Kimeridge, which contains the workable cement-stone, the Kimeridge coal with its bituminous shales and the fossiliferous beds atop, near Chapman's Pool. The vertebrate fauna of these coaly and sub-calcareous mudstones appears to have been abundant, whilst the molluscan fauna is poor in species, though individuals, chiefly small flattened bivalves, are numerous. *Am. biplex,** *Discina latissima,* and *Lucina minuscula* are common and characteristic. Indications of the Hartwell fauna, such as *Belemnites souichii,* etc., may be expected at Chapman's Pool.

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* *Proc. Geol. Assoc.*, vol. vi, p. 39; "Record of Excursions," p. 537.

"At about 580 ft. from the top of the series a change is noted. There is still what is called *Am.* "*biplex,*" along with some recognised Upper Kimeridge fossils, but with these are associated the so-called *Am. thurmanni* and *Exogyra virgula* (now seen for the first time). Thus about 70 ft. of beds, down to the base at Hen Cliff, are doubtful, but Blake classed them with the Upper Kimeridge. The stratigraphy immediately to the east of Hen Cliff is somewhat dubious, and until this is made perfectly clear we cannot be said quite to understand the position of the beds, estimated at 150 ft., which occupy the cliffs of Kimeridge Bay, and whose harder portions constitute the ledges. In his second paper ("Portland Rocks of England") Blake had no hesitation in referring these to the Lower Kimeridge.†

"Unquestionably the lowest beds seen on this part of the coast, including the Bench-rock, forming the Broad Bench on which the party stood during the explanations given by the Director, must be well within the Lower Kimeridge. This is proved by the presence of *Am. alternans* (in abundance) and several characteristic Lower Kimeridge ammonites; whilst immediately below the Bench-rock, and in the shales of Hobarrow Bay, exposed at low tide, may be found nearly all the characteristic ammonites of the Virgulian horizon, *e.g., Am. eudoxus* and *Am. longispinus,* together with *Exogyra virgula* in plenty, and an abundant Lamellibranch fauna.

"2. *Comparison of the Beds on either side of the Anticlinal.*—The very sharp dip on the north-west side seems to make the beds of Kimeridge Clay go into a very small space. We are probably dealing with at least 800 ft. of beds as developed on the south-east limb of the anticlinal. Is there as great a thickness on the north-west side? Perhaps not. The coal-bed, for instance, seems to have shrunk from 2 ft. on the south-east to 3 in. on the north-west, and the fact of its not being worked on the Brandy Bay side seems to accord with this attenuation. Cement stones have been picked up in Brandy Bay, and towards the top we get *Discina latissima* again, and the fossils of the Upper Kimeridge.

"3. *The Local Stratigraphy.*—The attention of the party had already been drawn to the repeated faults on the west side of Kimeridge Bay, where there was a succession of uplifts towards the north-west. This system of uplifts culminates in the Hobarrow Bay fault, presenting some curiously deceptive features, which a walk of a few hundred yards towards the north would enable the members to investigate at close quarters.

"The party accordingly advanced along the almost level surface of the Bench-rock until close under the cliff, where they could easily perceive the dislocation, whereby the platform on which they were standing is lifted some 50 ft. into the cliff on the north-west side. Owing to peculiar circumstances, which are best explained by reference to the accompanying section (Fig. 67), the throw of this very important fault had originally been estimated at only 6 ft."

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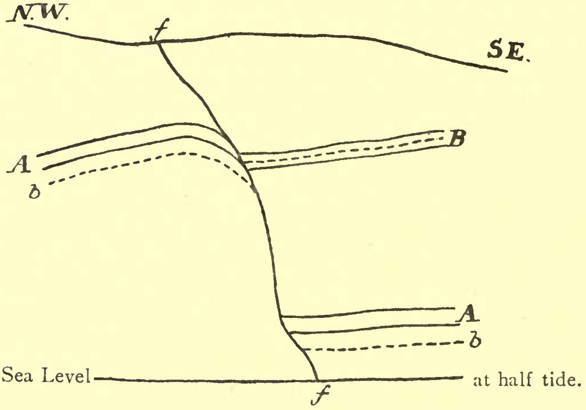
* See footnote on page 405.

† *Quart. Journ. Geol. Soc.*, vol. xxxvi, p. 195.

The Kimeridge coal is thus referred to in the 1882 report.* "The coal beds now worked are in the lower part of the Upper Kimeridge, and consist of a black bituminous coal, 2 ft. thick, and above this of a mass of bituminous shales 10 or 12 ft. thick, but variable as to quality. Some of this coal contains a large amount of gas. One analysis gives 61 per cent. of volatile matter with a balance of 13 per cent. carbon and 26 per cent. ash. The gas has a high illuminating power, but smells horribly. It is generally supposed that the hydro-carbons have been distilled from the putrefaction of animal matter. The material occasionally has a market for the production of asphalt and other compounds. These Upper Kimeridge beds have a somewhat local development, and have on the whole a different fauna from the Lower Kimeridge as exposed at Ringstead Bay. Palæontologically they are characterised by the absence of *Exogyra virgula*,

FIG. 67.—DIAGRAMMATIC SECTION OF A FAULT IN THE KIMERIDGE CLAY, HOBARROW BAY.—*W. H. Hudleston.*



A. The "Bench-rock," an impure and ferruginous cement stone, such as forms the Kimeridge ledges hereabouts. This one constitutes the Broad Bench, a rocky platform between Kimeridge and Hobarrow Bays.
B. The "Double-rock," a hard band of similar composition higher in the series.
b. Shale full of Lower Kimeridge fossils, including *Exogyra virgula* in great numbers, *Ammonites alternans*, etc.
f. Fault with downthrow to S.E., estimated at 45 ft. by Mr. Strahan.

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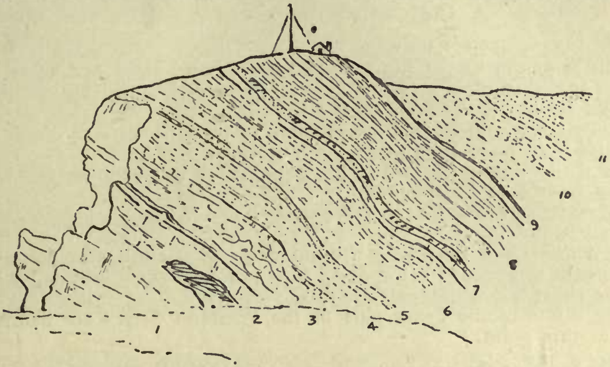
* *Proc. Geol. Assoc.*, vol. vii, p. 384.

Ostrea deltoidea, and *Rhynchonella inconstans*, and by the prevalence of *Lucina minuscula*, *Discina latissima*, and *Lucina lineata*. *Ammonites* '*biplex*' is very abundant."*

The party did not visit the coal workings on the 1882 excursion, but on the 1895 excursion the members succeeded in reaching the excavations. They reported that the industry seemed to be languishing, although piles of the material were seen to be collected in one or two places. It was remarked that pyritized specimens of *Ammonites pectinatus* were abundant in the coal, serving to show that it is on the horizon of the well-known and richly-fossiliferous Lower Portland Sands of Swindon. "Consequently we have no difficulty in believing that the Kimeridge Clay of Chapman's Pool is on the horizon of the Hartwell and Swindon Clays at least approximately."†

FIG. 68.—SECTION OF CLIFF AT BACON HOLE, MUPE BAY.
—*H. B. Woodward.*
(Reproduced by permission of the Controller of H.M. Stationery Office.)



11. Wealden Beds.	
10. Shales, etc., with Purbeck Marble.	Upper Purbeck.
9. *Unio*-Beds and Broken Shell Limestone.	
8. *Corbula* Beds. etc., shales and limestones.	Middle Purbeck.
7. Cinder Bed—Hard Limestone—Flint-Bed.	
6. Marls with conspicuous band of harder white marl.	Lower Purbeck.
5. Sandy and honey-combed bands : top of Hard Cockle Beds.	
4. *Cypris* Freestone, etc.	
3. Broken Beds merging downwards into Soft Cap.	
2. Caps with intermediate Dirt-bed.	
1. Portland Stone with *Ammonites giganteus*, etc.	

Chapman's Pool was visited by the members in both 1882 and 1896. It is a noted locality for Kimeridge Clay fossils, and on the second occasion, at least, plenty of time was allowed for collecting.

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* This last named fossil as usually identified from the Kimeridge Clay, is now regarded by Miss M. Healey as *Olcostephanus pallasianus*. *Quart. Journ. Geol. Soc.*, vol. lx(1904), p. 60.

† *Proc. Geol. Assoc.*, vol. xiv, p. 322. See A. Strahan's "Geology of the Isle of Purbeck, etc.," *Mem. Geol. Surv.*, p. 52 *et seq.*

The sections at Bacon Hole, Mupe Bay (Fig. 68), and at Gad Cliff (Fig. 66), give a good idea of the Portland and Purbeck succession in the western part of the Isle of Purbeck. The Portland beds can be studied at St. Albans Head and in the various quarries between that place and Durlston Head.

The Freestone beds of the upper part of the Portland series were at one time extensively worked in these quarries, and some of them are still in use to a small extent. The "Caves" at Tilly Whim, near Swanage, are disused workings for this stone. A view of them is shown in Plate XII (Fig. 2), where nearly the full thickness of the upper part of the Portland series is exhibited.*

Almost at the top of the section there is an oyster bed some 6 ft. thick consisting of a mass of *Perna bouchardi*. Many big blocks of this bed lie about the floor of the workings.

Below the *Perna* Beds there is some 15 ft. of limestone which does not appear to have been used for building stone here.

We then come to the oolitic freestone which has been worked in the "Caves" some 10 ft. thick.

Below this are the Chert Beds, well shown in the photograph, more than 20 ft. thick.

Next there is a limestone without chert at the top, but nodules of chert begin to appear in it about 5 ft. down, and eventually it becomes again a chert bed which extends to sea level.

The sands of the lower part of the Portland Series are below sea level at this point.

There is again an oyster bed in the Middle Purbeck a mass of the shells of *Ostrea distorta*, known as the "Cinder Bed." It is exposed in disused workings by the side of the driving-road from Swanage to the Anvil Point Lighthouse. The locality is almost north of the lighthouse and the bed is exposed for 30 yds.

The section in Durlston Bay will be easily made out with the assistance of Dr. Strahan's diagram, Fig. 69. There is a good view of the bay from the southern or Durlston Head end. The Cinder bed is clearly seen extending out from the cliff across the shore in the middle of the bay. Above it we see the Stone beds (7 of Fig. 69), and just beyond, a marked change in the dip of the strata will be noticed. It is caused by the first of the two faults shown close together in the middle of the diagram.

The first fault brings the Cinder bed well above the shore, and the second fault takes it to the top of the cliff near a house with a red roof. Samuel Beckles obtained much of his collection of mammalian remains from a quarry which he opened for the purpose near the top of the cliff and close to where this red-roofed house now stands.

If we now make our way down to the bottom of the Zig-zag Path close to the double fault and look back to the south, we

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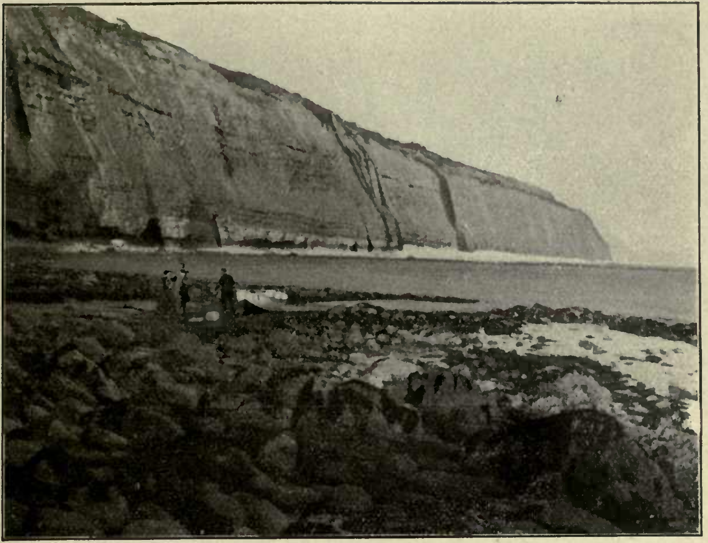
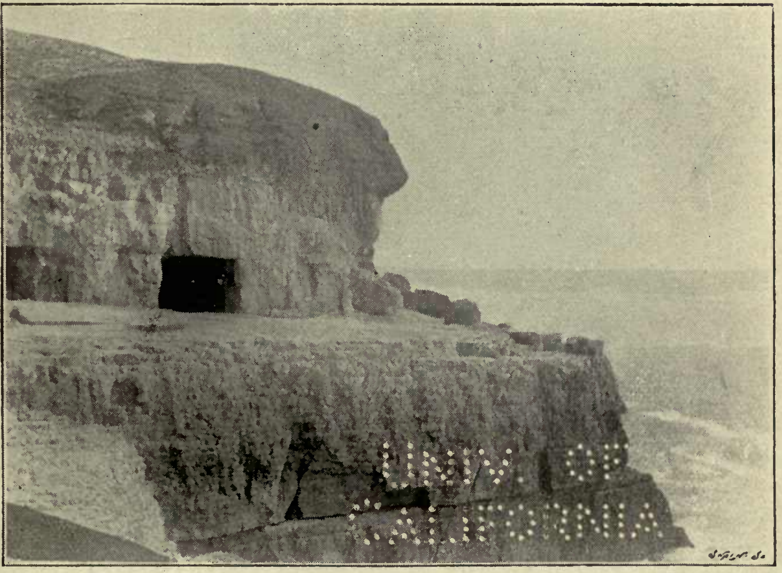
* The photo, Plate XII, Fig. 2, gives practically the same view as the sketch by Thomas Webster made in 1811, published in Englefield's "Isle of Wight," vol. ii, Plate XXXIII. It is interesting to compare the two.



[Photo by H. W. Monckton.

FIG 1.—PINHAY BAY, WEST OF LYME REGIS (Blue and White Lias).



UNIV. OF CALIFORNIA

[Photo by H. W. Monckton.

FIG. 2.—THE "CAVES" AT TILLY WHIM, NEAR SWANAGE.

To face page 406.

can easily follow the Cinder bed as it runs up the cliff. To the north of the faults we see a cliff largely composed of the Lower Purbecks, and there are usually blocks of gypsum from it lying on the shore. Making our way along the shore to the north, we can find the grey earthy bed from which the mammals have been obtained, but we shall not be likely to find specimens.*

The Cinder bed again comes down to the shore and forms a prominent ledge, and beyond it are ledges of the Stone beds.

The small fault shown in the diagram near Peveril Point is plainly seen in the cliff, and so are the curious contortions in the Upper Purbeck strata at the Point. The *Unio* beds are easily found and there was in 1908 a large slab covered with the shells, but specimens are not easily extracted.

The two marble beds crowded with *Paludina* are well exposed at the Point, and the Broken-shell limestone makes two long reefs which run far out to sea.

CRETACEOUS.

The Purbeck beds are followed at Swanage by a great thickness of Wealden strata, but the junction is hidden under Alluvium. A little to the north of the town there is a conspicuous cliff formed of these beds, consisting of sands and marl, with a little lignite in places and a band of coarse

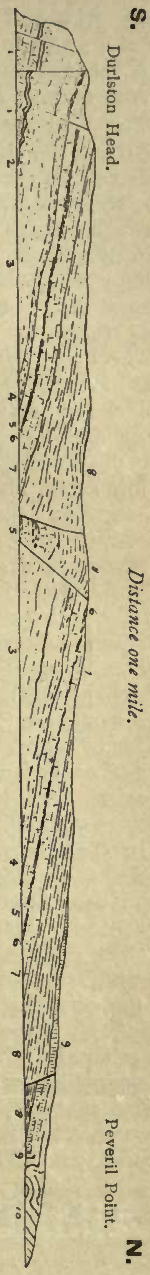


FIG. 69.—SECTION FROM DURLSTON HEAD TO PEVERIL POINT, SWANAGE.—*A. Strahan.*

Distance one mile.

3. Marls with gypsum
2. Caps.
1. Portland Stone.
} Lower Purbeck.

8. *Corbula* and Beef Beds.
7. Stone Beds.
6. Cinder Bed with *Ostrea distorta.*
5. Stone Beds.
4. Flint Bed, Black Shale and Mammal Bed.
} Middle Purbeck.

10. Purbeck Marble, etc.
9. Burr Limestone, etc.
} Upper Purbeck.

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* The bed can be found with the assistance of the diagram given by Mr. H. B. Woodward, "Jurassic Rocks of Britain," vol. v, p. 250. The Flint bed is easily found. Measure downwards from it.

quartz grit, and as we near Punfield Cove we find beds of sandstone and clay interbedded with the sands. At Punfield Cove the top of the Wealden series consists of shales with *Cyrena*, *Ostrea*, *Paludina*, and *Cypris*.*

The Wealden series crosses the Isle of Purbeck and again appears in the cliffs at Worbarrow Bay and Mupe Bay, and yet again near West Lulworth. At Swanage its thickness appears to be so great that Mr. Starkie Gardner suggested it could only be accounted for by supposing the beds to have been folded on themselves.†

The series, in any case, thins as we go westward and also becomes much coarser in texture, the clays and sands becoming sands and grits.

The Lower Greensand at Punfield Cove has a classical interest as having given rise to the Punfield controversy.

The section was carefully measured by the officers of the Survey and the position of the Perna-bed at the base of the series determined.‡

The Lower Greensand runs through the town of Corfe Castle, and on April 6th, 1896, our members examined a small but interesting section in the fossiliferous beds of the formation in the station yard.

The Lower Greensand, which is nearly 200 ft. thick at Punfield Cove, thins to less than 70 ft. at Mupe Bay, and is not seen in Dorset to the west of that place.

The Selbornian (Gault and Upper Greensand) is well seen at Punfield Cove, and the members of the party in 1896 obtained quite a number of well-preserved fossils, mainly from the zone of *Pecten asper*. The thickness is about 156 ft. Westwards, the Selbornian oversteps the Lower Greensand, then passes across the Wealden beds, and in West Dorset rests upon various members of the Jurassic series.

In 1898, on the visit to the Holworth House section already alluded to on page 396, Mr. Hudleston led the way to a road-cutting near South Down Farm, which showed the Lower Chalk and Chloritic Marl dipping at a high angle to the north.

"The district, he said, was one with stratigraphical peculiarities which are not exceeded in point of interest by any throughout the whole of England. On the hill slope above them was a bluff of Upper Greensand and Chloritic Marl overlain by Lower Chalk, all with a dip of about 70 deg. to the north. In the quarry below are to be seen Portlandian beds, which have a similar northerly dip. This high dip of the Cretaceous beds shows that the folding belongs to the system of post-Cretaceous disturbances. The disturbances so well marked in this district occurred at two distinct periods; the example before us belongs to the later of these periods, and is probably of Miocene age. Other disturbances would be seen in the course of the day, which can be proved to be of pre-Cretaceous age, because they pass under the Cretaceous beds without affecting them."[*]

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* See A. Strahan. "Geology of the Isle of Purbeck and Weymouth." *Mem. Geol. Survey*, 1898, p. 125.

† *Proc. Geol. Assoc.*, vol. xiii, p. 278.

‡ *Proc. Geol. Assoc.*, vol. vii, pp. 387-390, and A. Strahan, *op. cit.*, p. 135.

During the 1906 excursion to Lyme Regis the party examined a lane-cutting in the Selbornian at Hardown Hill, and a number of fossils were obtained from the Foxmould (zone of *Schloenbachia rostrata*),[†] and on another day some time was spent collecting from the Selbornian exposures on the road from Lyme Regis to Charmouth under the direction of Mr. W. D. Lang, of the British Museum.

The following are the local sub-divisions of the Selbornian group:[‡]

			feet.
UPPER GREENSAND.	Zone of *Pecten asper.*	Sands with bands and nodules of chert	50
		Greenish sands	
	Zone of *Ammonites* (*Schloenbachia*) *rostratus.*	Buff, brown and white sands—the Foxmould of De La Beche	75
		Cowstone Beds, sands with three bands of concretionary masses of calciferous sandstone	20
GAULT.	Zone of *Amm.* (*Hoplites*) *interruptus.*	Dark loamy and glauconitic sands and clays, with pebbly layer at base	25

The base of the Chalk in Dorset is marked by a few feet of glauconitic sandy chalk with phosphatic nodules. This bed is, however, probably not strictly an equivalent to the Chloritic Marl of the Isle of Wight, but simply the basement bed of the chalk corresponding to a slightly higher zone than the bed with *Stauronema carteri* of the Isle of Wight. It rests upon a somewhat waterworn surface of the Upper Greensand.[§]

There is a fine Chalk headland between Swanage and Studland with the rock known as "Old Harry" standing out in the sea in front, and this headland is celebrated amongst geologists as the place where the great overthrust fault of the Isle of Purbeck reaches the sea, and is seen in the cliff. This fault is admirably shown in the photograph which illustrates Dr. Rowe's paper on the "White Chalk of the English Coast—Dorset" in our PROCEEDINGS,[||] and its relation to the Chalk-zones will be seen from the diagram which is here reproduced (Fig. 70).

It will be noticed that the zones shown extend down to that of *Holaster planus*, and we find the section to be continued downwards between the point shown on the left of the diagram and Punfield Cove, as follows:

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[*] *Proc. Geol. Assoc.*, vol. xv, p. 300.

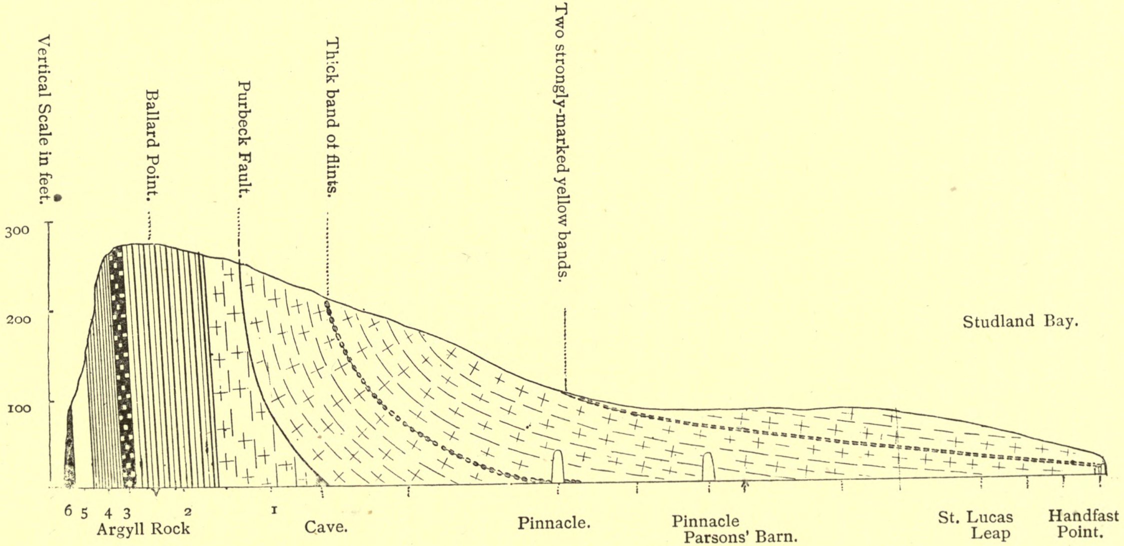
[†] *Proc. Geol. Assoc.*, vol. xix, p. 328.

[‡] For further details see *Proc. Geol. Assoc.*, vol. xix, p. 322.

[§] *Mem. Geol. Survey*, "The Cretaceous Rocks of Britain," vol. ii, p. 93.

[||] Vol. xvii, Plate viii, opposite page 35.

FIG. 70.—CLIFF-SECTION FROM BALLARD POINT TO STUDLAND BAY.—*A. W. Rowe.*



REFERENCE TO THE ZONES.

1. Zone of *Belemnitella mucronata.*
2. „ *Actinocamax quadratus.*
3. „ *Marsupites* { *Marsupites*-band. / *Uintacrinus*-band.
4. Zone of *Micraster cor-anguinum.*
5. „ *Micraster cor-testudinarium.*
6. „ *Holaster planus.*

Length of section—one mile.

Terebratulina-zone with a layer of hard, green-coated nodules about 20 ft. from the top.
Zone of *Rh. cuvieri.*
Zone of *Am. (Schloenb.) navicularis*, and equivalent to the zone of *Holaster subglobosus*, with the Belemnite marl at the top.
Zone of *Am. (Schloenb.) varians*, containing, in Dorset, *Holaster subglobosus* as well as *Am. varians.*

The Chalk runs through the Isle of Purbeck and comes out in the cliffs on the west at Worbarrow Bay, and westwards from that bay up to Holworth House there is a splendid series of sections from the Chloritic Marl to the zone of *Belemnitella mucronata* in the Upper Chalk. A full account of the sections will be found in the Memoir of the Geological Survey on the Cretaceous Rocks of Britain and in Dr. Rowe's paper on the White Chalk, in our PROCEEDINGS (vol. xvii, p. 1).

The Chalk again approaches the sea to the west of Lyme Regis, and the very beautiful cliffs between that place and Seaton were visited by us on April 16th, 1906. The highest Chalk found in these cliffs belongs to the zone of *Micraster cor-testudinarium*, and below it we find the zones of *Holaster planus*, of *Terebratulina*, and of *Rhynchonella cuvieri*, each with a fair thickness. The Lower Chalk, or zones of *Holaster subglobosus* and *Ammonites varians*, are, however, represented by only some 2 to 3 ft. of arenaceous chalk. The sections are fully described in Dr. Rowe's paper on the White Chalk of Devonshire in our PROCEEDINGS (vol. xviii, p. 1).

EOCENE.

There is a considerable area occupied by Eocene strata lying to the north of the Chalk Downs of the Isle of Purbeck, and a transverse section through the beds is afforded by the cliffs in Studland Bay. Unfortunately, the lower part of the series is not well seen in the cliffs, and much light was thrown upon them by the bore-hole, inland, at Bovington, which is described by W. H. Hudleston in Chapter XVI. (See p. 373.)

The junction of the Chalk with the overlying Eocene beds was examined by the Association on the south side of Studland Bay in 1894.* The Chalk is much piped and the ferruginous sand and sandstone of the *Reading Beds* has sunk into the pipes in an irregular manner.

The *London Clay* at Studland is hidden by vegetation, but the overlying *Bagshot Beds* form a low cliff. The cliff consists of variously-coloured sand with a good deal of iron-sandstone in places. Blocks of the sand, hardened into iron-sandstone, are often to be seen lying on the shore, and the well-known Agglestone on the heath near Studland is a mass of iron-sandstone weathered out of the Bagshot beds, but still *in situ.*

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* *Proc. Geol. Assoc.*, vol. xiii, p. 278.

Some irregular bands of clay are to be seen near the top of the cliff at Studland, and the pipe clay, which has for a long time been worked in the Corfe Castle—Wareham district, belongs to the Bagshot series.

One of the pipe-clay workings was visited on the 1882 excursion, and a characteristic sketch of a working will be found in the "Geology of England and Wales," by H. B. Woodward (2nd edition, 1887, p. 445).

The series on this coast from Studland to the mouth of Poole Harbour is termed Bagshot Beds on the Geological Survey Map, and it is termed Lower Bagshot by Mr. Starkie Gardner, being Bed 8 of his diagram reproduced on page 278 (Fig. 47).

On the Lyme Regis excursion of 1906 Mr. H. B. Woodward drew attention to a deposit on Hardown Hill which he thought might be of Bagshot age. It consisted of whitish clay with subangular flints and chert and pebbles of quartz and quartzite. On another day he showed us a somewhat similar deposit on the railway near Combpyne.*

PLATEAU DEPOSITS, PLEISTOCENE AND RECENT.

There is rather a scarcity of anything coming under the head of Plateau Deposits along the Dorsetshire cliffs. There is a certain amount of Clay-with-flints on the Chalk, and here and there we find gravelly accumulations which some observers believe to be in part of Eocene age.

Calcareous tufa.—Near Blashenwell Farm, about a mile west of south of Corfe Castle, there is a most interesting deposit of calcareous tufa, which has been fully described by Mr. Clement Reid.†

The section is as follows:

1. Black soil; at its base Roman coins, Romano-British pottery, shells of oysters, whelk, cockle, *Helix aspersa, H. ericetorum, H. virgata,* etc. 1 ft.
2. *(a)* Hard tufa with leaves of hazel, elm and oak, flint-flakes, bones of pig and deer, limpets and other marine shells, land-snails, including *Clausilia laminata, Bulimus montanus,* etc., much charcoal.
   (b) Loamy and marly tufa, with small land-shells, occasional *Limnæa truncatula,* rare flint-flakes, and charcoal.
   (c) Loam with stony base. Total of 2 = 8 ft.

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* *Proc. Geol. Assoc.*, vol. xix, pp. 329, 333.

† *Proc. Dorset Field Club*, vol. xvii (1896), p. 67, and see also A. Strahan, "The Geology of the Isle of Purbeck, etc.," *Mem. Geol. Survey*, 1898, p. 210.

"The deposition of the tufa had ceased before the formation of the Roman layer, and before a grave, believed to have been of Neolithic age, had been dug."*

The Valley Gravels of the district and the Chesil Beach† and the "Blown Sand" of Studland Bay have attracted our attention and given rise to discussion on our excursions, but we have not space in which to deal with them here.

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* Strahan, *op. cit.*, p. 211.

† On this subject the recently published Report of the Royal Commission on Coast Erosion should be consulted.

CHAPTER XVIII.

THE ISLE OF WIGHT.

By R. S. HERRIES, F.G.S.

NO district lends itself better for a descriptive article than the Isle of Wight. Its natural boundaries, its shape, and its general configuration all tend to give it a distinct position. It has, moreover, a range of geological formations of a most interesting and, to some extent, of a unique character, and presents the most accessible example of stratigraphical peculiarities, in its great monoclinic fold, to be found within easy reach of London. It has consequently been a favourite resort of teachers and their students, and has been on several occasions the object of excursions of the Geologists' Association. The following are the dates: 1864 (*Geological and Natural History Repertory*, July, 1866); June, 1881 (*Proc. Geol. Assoc.*, vol. vii, p. 185); March, 1891 (*Proc. Geol. Assoc.*, vol. xii, p. 145); April, 1895 (*Proc. Geol. Assoc.*, vol. xiv, p. 99); and June, 1906 (*Proc. Geol. Assoc.*, vol. xix, p. 357).

PHYSICAL FEATURES.

The Isle of Wight is in shape a lozenge, with the points corresponding to those of the compass. Its length from east to west is 22½ miles, and its breadth from north to south 13 miles. It is bounded on the north-west by the Solent, on the north-east by Spithead, and on the south by the English Channel. Its chief feature is the long range of Chalk Downs coincident with its longest axis, running from the Needles on the west to Culver Cliff on the east, though the extreme east point of the island is the Tertiary Foreland, the other horn of Whitecliff Bay just north of the chalk cliffs. There is a second prominent feature in the mass of Downs occupying the south point of the island and the country to the east of it from St. Catherine's Down to Shanklin, which mass attains a higher elevation even than the main ridge, the highest point being St. Boniface Down. 787 ft. above the sea. These two elevations are the two sides of an anticlinal fold, and may be compared on a small scale with the North and South Downs of Surrey and Sussex, though what would correspond to the Weald is here divided into two parts, the Lower Greensand beds being continuous between them, just as if the Weald were cut in half and the two halves placed back to back.

In another way, the Isle of Wight resembles the Weald district, in that its principal rivers cut through the Chalk escarpment, which is generally taken to be a proof that the existence of the rivers dates from a period when the upheaval first began and before there had been any appreciable denudation. These rivers are the Medina, the Eastern Yar, and the Western Yar. The Medina rises in the Greensand and Gault on the northern flank of the southern range of downs, and flows due north through the gap at Newport to the sea at the apex of the island at Cowes, thus dividing it into two almost equal halves. The Eastern Yar rises a short distance east of the Medina, with which it is parallel for four or five miles before turning east. Near Sandown it again takes a northerly trend through the gap in the chalk at Brading, and flows into the sea by Brading Harbour. Probably the main river came through the gap from the south, rising on the Wealden or lower beds, now, except for the small fragment at Sandown, beneath the waves. The Western Yar, as it now exists, rises within the gap of the chalk at Freshwater Gate, quite near the sea, and flows northwards to the opposite coast at Yarmouth. The width of this valley makes it clear that this is only a small relic of a much larger river, the main branch of which probably came from the now submerged Wealden beds to the south. There can be little doubt, as Mr. Codrington* pointed out many years ago, that the river gravels of Brixton and Compton Bays mark the channel of an old tributary of the Yar coming from the east, the only present remains of which are the streams that fall into those bays through the various chines. All these Isle of Wight rivers were, however, themselves tributaries of a great river which flowed from the west along the Dorset and Hampshire syncline, now represented, as well pointed out in the Survey Memoir, by the Frome in its upper course, and the Solent and Spithead in its lower.†

No one who looks at the map of the South of England, and still less if he stands on the Downs above the Needles and looks westwards towards the Isle of Purbeck, can doubt that the Isle of Wight once formed part of the mainland. Not only have we on the north the diamond-shaped island fitting exactly into the correspondingly shaped gap in the Hampshire coast, but on the west we have the strata, with the exception of the higher Oligocenes, which are confined to the island, repeated bed for bed on the opposite coast, from the Headon Beds at Hordle, in Hampshire, to the Wealden at Punfield, in Dorset. The great anticlinal fold (see Figs. 71 and 72) which brings the beds on its northern side into a vertical position in the Isle of Wight, is continued into Dorset, so that the Chalk of Ballard Point is the counterpart of that of the Needles, and the Lower Tertiaries of Studland Bay of the similar beds in Alum Bay.

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* *Quart. Journ. Geol. Soc.*, vol. xxvi, p. 528.

† C. Reid and A. Strahan, *Mem. Geol. Survey*, "Isle of Wight," 2nd Edition, 1889.

The question then arises, how and when did the separation from the mainland occur? For the answer we must turn to the river systems of the Isle of Wight above described. It will be seen by anyone visiting Sandown or Freshwater, that a very slight alteration of the level of the land, or a very slight excavation of the alluvial soil of the two rivers Yar, would suffice to make three islands of the present Isle of Wight. The sea, having once isolated the two ends of the island, would slowly but surely proceed to reduce the two islets, till eventually they would disappear altogether. So we must suppose that the sea gained access from the south or anticlinal side to the upper waters of a river somewhere between the Isle of Wight and Purbeck, which, like the Medina and the two Yars, flowed through a gap in the Chalk range, and so got through on to the soft sands and clays of the Eocene Beds in the synclinal valley of the Frome. This may have happened in more than one such valley, and so the first stage may have been a series of islands stretching across what is now Christchurch Bay. The sea, having once got into the estuary of the Frome, would soon work on the easily yielding Eocene Beds, and the old lower part of that river would become an arm of the sea, as it is to-day, in the form of the Solent. Such a hypothesis presupposes the existence of valleys practically in their present form, so that the date of the separation must be subsequent to the formation of the present valley system—that is to say, in, comparatively speaking, recent times.*

GEOLOGY.

The Isle of Wight consists of a southern anticline and a northern syncline, the division between which may be taken at the central ridge (see Figs. 71 and 72). The Chalk comes up again on the other side of the Solent at Portsdown Hill. The anticline is really a double one, or perhaps two branches of the same one, the force causing it having been stronger on the eastern side, so as to drive the axis farther to the north, and cause a more extensive tilting of the Tertiary Beds, so that while at Alum Bay the Eocene Beds alone of the Tertiaries are vertical, the Headon Beds above becoming almost horizontal, at Whitecliff Bay the verticality is continued into the Bembridge Beds, which gradually bend round and become horizontal. It is usual to speak of the Brixton and Sandown anticlines, from the two distinct occurrences of the lowest beds exposed—namely, the Wealden in those two bays—and a glance at the map will show that the axis of the exposure of the Wealden Beds on the west side, namely, in Compton and Brixton Bays,

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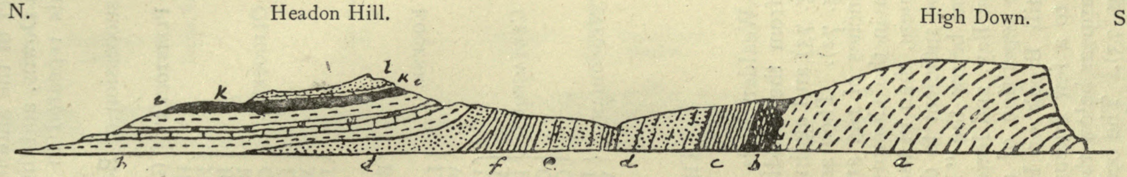
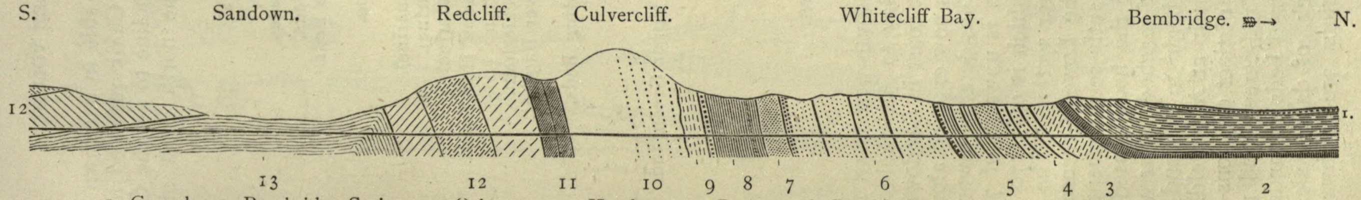
* See A. Strahan, *Proc. Geol. Assoc.*, vol. xiv, p. 405.

FIG. 71.—SECTION ACROSS ALUM BAY FROM HEADON HILL TO HIGH DOWN.—*After H. W. Bristow.*
(*Reproduced from H. B. Woodward's "Geology of England and Wales."*)



(*l*) Plateau Gravel.
(*k*) Bembridge Beds.
(*i*) Osborne Beds.
(*h*) Headon Beds.
(*g*) Headon Hill Sands.
(*f*) Barton Clay.
(*e*) Bracklesham Beds.
(*d*) Lower Bagshot Beds.
(*c*) London Clay.
(*b*) Reading Beds.
(*a*) Chalk.

FIG. 72.—SECTION FROM SANDOWN TO BEMBRIDGE.—*Record of Excursions.*



1. Gravel. 2 Bembridge Series. 3. Osborne. 4. Headon. 5. Barton. 6. Bracklesham. 7. Lower Bagshot. 8. London Clay. 9. Reading Beds. 10. Chalk. 11. Upper Greensand and Gault. 12. Lower Greensand. 13. Wealden.

is considerably south of that on the east side in Sandown Bay. The effect of the anticline is to get the Chalk repeated in the Southern Downs, and the effect of the syncline to get the Oligocene Beds repeated in succession on the north coast of the island.

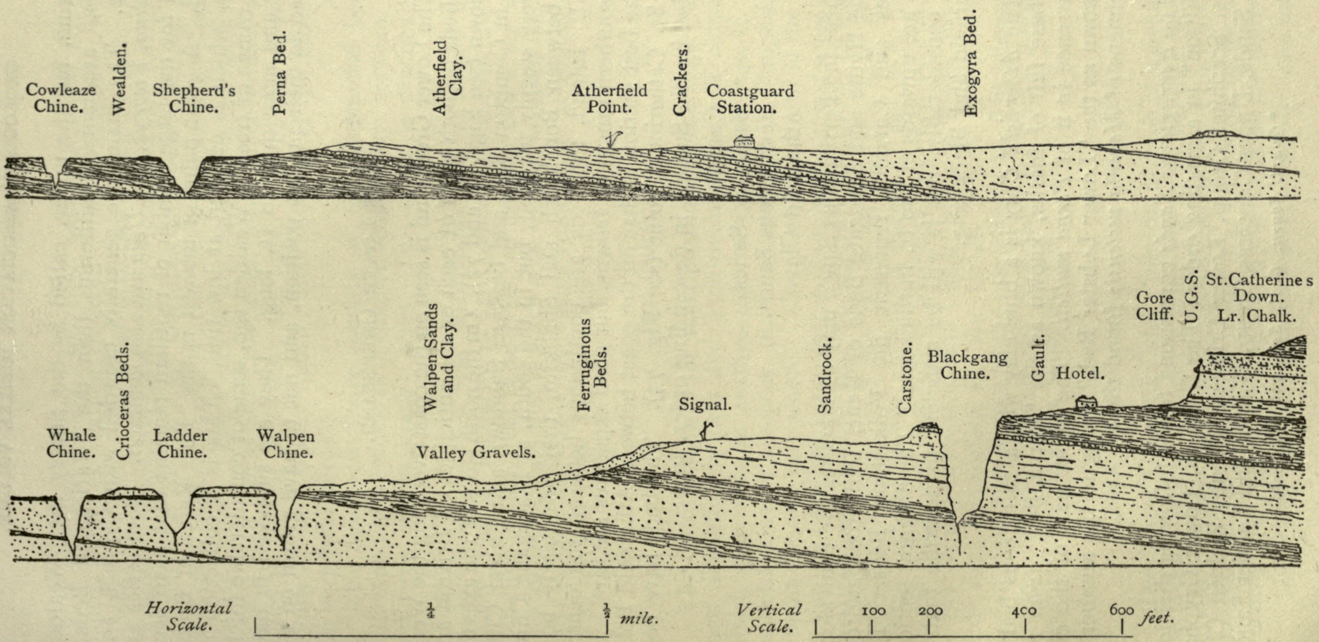
The succession of Beds is as follows:

FLEISTOCENE	Gravels of various ages.	
OLIGOCENE.	Hamstead Marine Beds. Hamstead Estuarine Beds. Bembridge Marls. Bembridge Limestone. Osborne Beds. Upper Headon (Estuarine). Middle Headon (Marine). Lower Headon (Estuarine).	
EOCENE.	Bagshot Beds.	Headon Hill Sands Barton. Bracklesham. Lower Bagshot.
	London Clay. Woolwich and Reading Beds.	
CRETACEOUS.	Upper Chalk. Middle Chalk. Lower Chalk. Chloritic Marl and Upper Greensand. Gault.	
NEOCOMIAN.	Lower Greensand. Wealden Beds.	

THE WEALDEN BEDS.

The Wealden Beds are seen on the south-west coast of the island, from the middle of Compton Bay to Atherfield Point (see Fig. 73) and again on the south-east coast in Sandown Bay (see Fig. 72). They are the lowest beds now exposed along the two branches of the anticlinal axis. Considerably lower beds are seen in the Compton section, which is upwards of 700 ft. in thickness, than in that of Sandown, which is only 170 ft., so it will be sufficient to describe the former section. The strata rise from below the "Perna-bed" of the Lower Greensand in Compton Bay, and lower beds are constantly seen (except for a possible repetition of about 200 ft. of the beds caused by a fault), till Brook or Hanover Point is reached, after which, subject to a few fluctuations, the beds begin to descend again and disappear below the "Perna-bed" again at Atherfield Point (see Fig. 73). The beds consist of two distinct divisions—viz., a lower series, about 500 ft. thick, of red, green, and purple variegated marls and clays, with occasional beds of sandstone; and an upper series, about 200 ft. thick, of dark shales with layers of shelly limestone. Both divisions are freshwater or

FIG. 73.—SECTION FROM COWLEAZE CHINE TO ST. CATHERINE'S DOWN, SHOWING BEDS FROM THE WEALDEN TO THE LOWER CHALK.—*A. Strahan.*



estuarine, but the upper, called by the Survey the "Wealden Shales," are more fossiliferous than the "Variegated Beds" below. The shales are generally crowded with Cyprids, and *Paludina*, *Vicarya*, and *Unio* are also common. Both series are noted for the large number of reptilian remains that have been found. A great point of interest is the "Pine Raft" at Brook Point, which is exposed at low tide. This is a collection of solid trunks of trees of Wealden age, some of considerable thickness, and more than 20 ft. long. They are supposed to have drifted to their present position, and not to have grown on the spot.

THE LOWER GREENSAND.

The Lower Greensand is seen on the coast overlying the Wealden Beds on both sides of each of the anticlines of Brixton and Sandown (see Figs. 73 and 72). On the north sides of the axes the beds in Compton Bay, and between Sandown and Culver Cliff, are very steeply inclined, but in the south, at Blackgang Chine and between Bonchurch and Shanklin, they are nearly horizontal. Inland, the beds are continuous between the central and southern ranges of Downs, but good exposures are rare. By far the best section is that on the coast between Atherfield Point and St. Catherine's Point (see Fig. 73). The beds have been divided by the Survey, in descending order, into:

Carstone.
Sandrock Series.
Ferruginous Sands.
Atherfield Clay.

Of these the Ferruginous Sands may be taken as the equivalents of the Hythe and Sandgate Beds of Kent, while the Sandrock Series and Carstone represent the Folkestone Beds. The beds are upwards of 800 ft. in thickness. The different sections vary considerably, but it will be sufficient to describe that of Atherfield and Blackgang.

The *Atherfield Clay* is a blue clay with a calcareous bed at the base full of fossils, known as the "Perna Bed" from the occurrence in it of *Perna mulleti*. The upper part of the clay is known as the "Lower Lobster Bed," owing to the number of specimens of *Meyeria vectensis* found there.

The *Ferruginous Sands* correspond to the following divisions of Fitton* in ascending order: The Crackers, Lower Gryphæa Beds, Scaphites Group, Lower Crioceras Group, Walpen Clay and Sands, Upper Crioceras Group, Walpen and Ladder Sands,

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* *Quart. Journ. Geol. Soc.*, vol. iii, p. 289.

Upper Gryphæa Beds, Cliff End Sands, Foliated Clay and Sands, Sands of Walpen Undercliff, and Ferruginous Beds of Blackgang Chine. These subdivisions consist of more or less ferruginous sands and clays, and many of them are named after characteristic fossils, *e.g.*, Gryphæa *(Exogyra sinuata)*, Scaphites, and Crioceras; others after localities such as Walpen and Ladder Chines. The Crackers are remarkable for large blocks of very hard blue-hearted limestone, which when broken up are found to be full of fossils; the upper part of this division is known as the "Upper Lobster Bed." Many of the other beds are very fossiliferous.

The *Sandrock Series* consists of several massive beds of yellow and white sand, with thinner beds of clays between. It is well seen at Blackgang Chine. This series is practically unfossiliferous.

The *Carstone* is a very ferruginous grit, so named by the Survey from its similarity to the Carstone of Norfolk and Lincolnshire, which, like these beds, occurs just below the Gault. The fossils indicate that it is the zone of *Am. mammillaris.* The beds thicken eastwards, increasing from 12 ft. at Blackgang to 72 ft. at Red Cliff, east of Sandown.

THE GAULT.

The Gault occurs in the same positions as the Lower Greensand, immediately over and conformable to it. It consists of bluish clay with an average thickness of about 140 ft. The sections however are poor, the best being that in Compton Bay. Fossils are also very scarce. The principal interest in the Gault of the Isle of Wight is the part it plays in producing some of the finest scenery—namely, the "Undercliff" between St. Catherine's Point and Ventnor, and the "Landslip" to the east of Bonchurch. Owing to the impervious nature of the clays holding up the water, and to the slight southerly dip, there is a tendency of the Upper Greensand and Chalk above to break away and slide over the surface of the Gault, which is consequently strewn with great masses of the overlying beds. The phenomenon is similar to that which has occurred near Lyme Regis, the medium there however being the Lias.

UPPER GREENSAND AND CHLORITIC MARL.

The Upper Greensand and Chloritic Marl may conveniently be taken together, authorities differing as to whether the latter should be classed with the Upper Greensand or with the Chalk, though Mr. Jukes-Browne* places it at the bottom of the Chalk, classing the Upper Greensand with the Gault as the Selbornian.

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* *Mem. Geol. Survey.* "The Cretaceous Rocks of Britain," vol. i, pp. 1 and 2.

The formation is of considerable importance as contributing very much to the scenery of the Undercliff and Landslip, and as supplying a good building-stone from the freestone beds which underlie the Chert Beds. The Upper Greensand is divided into the Malm Rock below and the Chert Beds above. The Malm Rock consists of sands with raggy partings, and is from 70 to 80 ft. thick; the Chert Beds consist of bands of chert and sands from 12 to 24 ft. thick, forming a very strong feature. The Chloritic Marl lies above the Chert Beds and is about 15 ft. thick. It consists of calcareous sands full of green matter, which was formerly thought to be chlorite, but is in fact glauconite. It contains numerous phosphatised casts of Ammonites and other fossils. The occurrence of the Upper Greensand, the fossils of which may be collected from fallen blocks in the Undercliff, is similar to that of the Gault.

THE CHALK.

The Chalk, which as usual succeeds the Upper Greensand, forms, as has already been stated, the great central ridge of Downs, and it also caps the southern mass. There are many exposures along the ridge, as well as the two great coast sections at the east and west ends of the island. The Chalk has been divided into Upper, Middle, and Lower, but more recently according to zones. The Upper Chalk is often distinguished as the Chalk with Flints.

The *Lower Chalk* was divided by Dr. Barrois* into the zone of *Scaphites æqualis* below and the zone of *Inoceramus labiatus* above. The former is the Grey Chalk or Chalk Marl. According to the Survey, the Chalk Marl at Culver Cliff is 120 ft. thick and the bed above 86 ft. The Lower Chalk occurs in the Southern Downs as well as in the central ridge, making an outlier on St. Catherine's Hill (see Fig. 73), and a larger mass from above St. Lawrence to beyond Bonchurch. St. Boniface Down is capped by the Middle Chalk and probably a few feet of Upper Chalk.

The *Middle* and *Upper Chalk* have been so recently and so exhaustively dealt with by Dr. Rowe in the last of his series of papers on "The Zones of the White Chalk of the English Coast," published in our PROCEEDINGS,† that a very short summary will suffice. The reader will also find in the paper referred to a most useful series of coloured plans, prepared by Mr. C. Davies Sherborn, showing the zones of the Chalk all along the central ridge from the Needles to Culver Cliff, for in this paper Dr. Rowe has departed from his usual custom of confining himself to the coast sections, and has given descriptions of practically every exposure of the beds throughout the island, except such as are found on the Southern Downs. The following are the zones in ascending order: *Rhynchonella cuvieri*, *Terebratulina gracilis*, *Holaster planus*, *Micraster cor-testudinarium*, *Micraster cor-anguinum*, *Marsupites testudinarius* with the *Uintacrinus* band, *Actinocamax quadratus*, and *Belemnitella mucronata*. The beds are always dipping at a very high angle and are well exposed in the coast sections from Freshwater Bay to Alum Bay at the west end of the island, and at the Culver Cliff at the east end. The lower zones and the lower part of the Holaster planus zone are flintless; above that the flints occur in fairly regular courses. Dr. Rowe gives the total thickness at the west end as 1,471 ft., and at the east end as 1,213 ft. Full references to the work of previous authorities are given, and full justice is done in particular to the researches of Dr. Barrois. Dr. Rowe notes that the Chalk Rock proper does not exist, but that there is a somewhat similar bed at a lower horizon in the zone of *Terebratulina gracilis*, which he calls "The Spurious Chalk Rock."

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* *Ann. Soc. Geol. Nord.*, tome i (1875), p. 74.

† *Proc. Geol. Assoc.*, vol. xx, p. 209.

EOCENE.

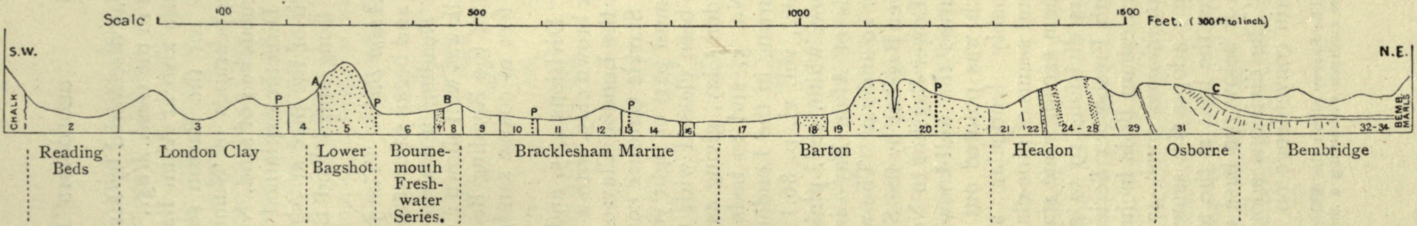
The Tertiary beds of the Isle of Wight were formerly all classed as Eocene, but it is now more usual to separate off the beds above the marine Barton as a distinct division under the name of Oligocene. The Eocene Beds therefore consist of Woolwich and Reading Beds, London Clay, and Bagshot Beds. They overlie the Chalk immediately north of the central ridge throughout the island at a very high angle, being in fact almost vertical. They may be seen at various points where worked in brickfields, but the two best-known exposures are the coast sections of Alum Bay at the west and Whitecliff Bay at the east end of the island. The beds are not of great interest in themselves, but they can be very easily studied owing to their practical verticality and the sharp contrasts of clay and sand beds.

The *Woolwich* and *Reading Beds* are probably freshwater beds, and are practically devoid of fossils. The *London Clay* is marine and has fossils, but not in great abundance. The *Bagshot Beds* are divided into *Lower Bagshot*, *Bracklesham*, and *Barton*, above which comes a bed of sands now generally classed with the Barton, formerly called *Upper Bagshot*. This name is very misleading, as the beds are at a much higher horizon than the similarly named beds in the London Basin, which are of Lower Barton age. It is best therefore to call them by the local name of *Headon Hill Sands*. The *Lower Bagshot Beds* are interesting as containing at Alum Bay the well-known Leaf Bed. The *Bracklesham Beds* have been subdivided by Mr.

Starkie Gardner into the *Bournemouth Freshwater Series* below and the *Bracklesham Marine Beds* above. At Alum Bay the beds are not very fossiliferous, but at Whitecliff Bay many of the characteristic Bracklesham fossils are found, including *Nummulites lævigatus* and the tiny *Nummulites elegans* (variety *variolarius*). The *Barton Beds* are not very fossiliferous at either section, being in marked contrast to the similar beds of the mainland. At Barton however there is an exposure of several miles of nearly horizontal beds, which can be easily examined on the broken slopes of the cliffs, whereas in the Isle of Wight the whole series is compressed into about a hundred yards of cliff, which is not well adapted for a collecting ground. The *Headon Hill Sands* are practically unfossiliferous, being again in contrast with their probable equivalents on the mainland. the *Long Mead End Beds*, in which pockets of fossils are found. The sections may be best described by quotations from the report of the "Excursion to the Tertiary Beds of the Isle of Wight," 1895 (*Proc. Geol. Assoc.*, vol. xiv, p. 99).

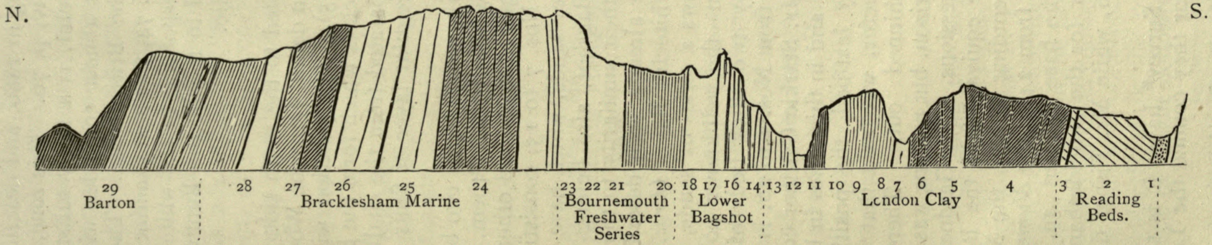
Whitecliff Bay. "Proceeding northwards the party examined the Tertiary Beds in detail. The mottled Woolwich and Reading clay (Bed 2 of Fig. 74) was well shown, but no fossils were found in it; indeed, so far as Mr. Monckton knew, none but Ostracoda and plants have been found in this formation in the Isle of Wight. The basement bed of the London Clay yielded *Ditrupa plana* and several casts of bivalves. Nos. 3 and 4 of Fig. 74 represent the London Clay, and the Director pointed to the intercalation of grey and yellow sands between beds of undoubted London Clay as affording evidence in favour of the opinion of Mr. Starkie Gardner, that the grey sandy beds at Alum Bay (Nos. 7 to 13 of Fig. 75) should also be included in the London Clay. The Lower Bagshot at Whitecliff Bay (No. 5 of Fig. 74) is a sand with a well-marked layer of iron sandstone at the base, and with a pebble-bed of nearly a foot thick at the top, separating it from Nos. 6, 7, and 8, which Mr. Starkie Gardner correlates with his Bournemouth Freshwater Series, taking the greenish clayey bed, with layers of *Cardita*, No. 9, as the base of the marine part of the Bracklesham Beds. Many fossils were obtained from bed 9 and a quantity of *Nummulites lævigatus* from bed 12. The waterworn condition of many of the fossils in bed 13 was remarked, and the party proceeded to collect from Nos. 14 and 16, the small Nummulite, *N. elegans* (variety *variolarius*), being found in great abundance. After luncheon the approximate position of the zone of *Nummulites elegans* (variety *Prestwichianus*) was pointed out in the lower part of bed 17, though owing to the overgrown and obscure condition of this part of the section this zone can seldom if ever be seen, except on the foreshore, where

FIG 74—SECTION AT WHITECLIFF BAY.—*W. Topley* (*after J. Prestwich*).



A = Horizon of plant bed at Alum Bay. B = Ditto at Bournemouth. C = Horizon of Insect Bed at Gurnard Ledge. P = Pebble Beds.

FIG. 75.—SECTION AT ALUM BAY.—*J. S. Gardner.*



The numbers of the beds in this section and the one above are those used by Sir Joseph Prestwich, and the divisions those of Mr. Starkie Gardner.

The scale only refers to Fig. 74.

it was discovered by Mr. H. Keeping in 1886, and described by him in the *Geol. Mag.*, dec. 3, vol. iv, p. 70. This zone, which occurs also at Alum Bay and Highcliff, is a fairly satisfactory base for the Barton series, and it almost coincides with the disappearance of Nummulites in the British area. The conspicuous bed of sand, No. 20 of Fig. 74, was next examined, and the Director explained that it corresponded to the white sands north of the pier at Alum Bay, and to the Becton Bunny Beds and Long Mead End Beds of Hordle."

Alum Bay. "The party proceeded to the south side of the bay and began to examine the beds in detail, from the Woolwich and Reading upwards (see Fig. 75). The junction with the Chalk was well shown; the mottled clays which form the greater part of the Reading Beds, being separated from the chalk by a few feet of coarse sand, with an irregular layer of flints at the base.

"Divisions 4, 5, and 6 of Fig. 75, consisting of two beds of dark brown clay, with a bed of yellow sand between them, represent the London Clay of the Geological Survey and others, but Mr. Starkie Gardner considers that Nos. 7 to 13, consisting for the most part of light yellow and grey sands, which have generally been classed with the Lower Bagshot, also belong to the London Clay, giving as his reason their similarity to the sands of No. 5, and to beds which have already been described as occurring in the London Clay at Whitecliff Bay. (*Proc. Geol. Assoc.*, vol. vi, p. 86.) Then follows a series of sands, bright yellow, white, red, pink, and brown—the well-known coloured sands of Alum Bay—interrupted by two thick beds of clay, Nos. 20 and 24. The whole series, from Nos. 7 to 26, is called Lower Bagshot by the Survey, but Mr. Starkie Gardner confines the Lower Bagshot to Nos. 14 to 18, and in this series in bed 17 occurred the well-known Alum Bay leaf-bed, the position of which was pointed out by the Director, who said that it was probably lenticular and had thinned out. There are several seams of pipe-clay on this horizon, but nothing was found in them except some stalk-like impressions. Mr. Gardner considers divisions 19 to 23 to be the equivalent of the Bournemouth Freshwater Series, while, according to him, the Marine Bracklesham Beds include the beds from 24 to the *Nummulites Prestwichianus* zone, 47 ft. above the base of bed 29. The Survey adopts the same upper limit for the Bracklesham, but places the base at the top of bed 26, while Mr. Fisher did not take it below the base of bed 29.

"The divisions adopted by the Survey* have, it is true, a certain convenience on their side, for they confine the London

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* The Survey admit the difficulty and apparently adopt the old divisions for want of definite evidence warranting a change.

Clay to the dark brown clays below the sandy series, and they keep all the coloured sands—which, except for leaves, are entirely unfossiliferous—in one division, viz., the Lower Bagshot; but when we come to compare the beds with those at Whitecliff Bay we are met by the suspicious circumstance, that whereas the total thickness from the base of the London Clay to the top of the Bracklesham is much the same, there is an extraordinary discrepancy in the thickness in the component beds, and the advantage of Mr. Gardner's arrangement becomes apparent, as will be seen from the following tables, in which the Survey measurement of the beds has in each case been adopted:

SURVEY DIVISIONS.	ALUM BAY.	WHITECLIFF BAY.
	Feet.	*Feet.*
Bracklesham	*155 ...	†570
Lower Bagshot	662 ...	98
London Clay	233 ...	320
	1,050	988

MR. STARKIE GARDNER'S DIVISIONS.	ALUM BAY.	WHITECLIFF BAY.
	Feet.	*Feet.*
Bracklesham Marine	*419 ...	†447
Bournemouth Freshwater ...	152	123
Lower Bagshot	76 ...	98
London Clay	403 ...	320
	1,050	988

"Whichever grouping is adopted, the fact remains that the beds have undergone a great change of character between the east and west ends of the island, unfossiliferous sands being developed at Alum Bay in place of the great deposits of clay full of marine shells at Whitecliff Bay, but if Mr. Gardner is right, the other difficulty, viz., the variations in thickness of the beds, is at any rate got over."

OLIGOCENE.‡

The beds above the Bagshot Beds belong to a very well-marked and distinct series, to which the name of Fluvio-Marine Beds was given by Edward Forbes. In 1880 Professor Judd suggested the adoption of the term "Oligocene," which was already in use on the Continent for beds of similar age and character. The beds consist of alternations of freshwater and estuarine beds with occasional bands of purely marine deposits. They evidently mark the course of some considerable river. These Isle of Wight deposits and similar beds on the opposite coast of Hampshire and in the New Forest are the only representatives in Britain of the Oligocene formation, and in the Isle of Wight alone are beds of this age found newer than the Headon.* The Oligocene is generally divided into *Headon Beds*, *Osborne Beds*, *Bembridge Limestone and Marls*, and *Hamstead* (or *Hempstead*) *Beds* in ascending order. It is not quite apparent why these divisions have been adopted, as in some cases much more marked distinctions occur within the divisions themselves, and there does not seem any very good reason for separating others, as, for instance, the Upper Headon Beds and the Osborne Beds, or the Bembridge Marls and the lower or estuarine division of the Hamstead Beds. The principal marine beds are the Middle Headon and the upper part of the Hamstead Beds, while there is a minor marine bed at the bottom of the Bembridge Marls, which is somewhat local, as it is not known at the west end of the island. These beds occupy the whole of the north half of the island after the somewhat narrow band of Eocene beds, as they occur in a syncline, so that while they are first seen at Alum and Whitecliff Bays dipping to the north, they again recur in succession farther north dipping to the south. The coast sections are still the best for studying these beds. At Whitecliff Bay the succession of Headon, Osborne, and Bembridge Beds follows on after the Eocene, still nearly vertical (see Figs. 72 and 74) till the Bembridge Limestone gives a sharp fold, bringing it into a nearly horizontal position, being followed by the overlying marls. At Alum Bay, on the contrary, as has already been pointed out (see p. 416), the verticality of the beds ceases with the Headon Hill Sands, and these and the succeeding beds gradually assume a much less steep dip till, as the coast turns eastwards under Headon Hill, they become nearly horizontal (see Fig. 71). Here they can be very well studied and collected from, the various beds being easily accessible, and the fossils strewn about on the weathered terraces of the hill. The hill consists of the Lower, Middle, and Upper Headon Beds, the Osborne Beds, and the Bembridge Limestone, capped and to a large extent masked by Plateau Gravel.

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* Including 47 feet of Bed 29, Fig. 75.

† Including 80 feet of Bed 17, Fig. 74.

‡ See Note at end of this chapter.

The *Lower* and *Upper Headon Beds* consist of alternations of green and grey clays and buff and white limestones with occasional beds of sand. The fossils of the clays indicate an estuarine origin, while the limestones are full of freshwater shells, *Limnæa*, *Paludina*, etc., and even contain land shells such as *Helix*.

The *Middle Headon*, on the other hand, are marine with an admixture of estuarine fossils, and contain about the middle a very rich bed of purely marine fossils, known to collectors as the "Venus" Bed, from the occurrence in great abundance of

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* But see Chapter xvi, p. 381, footnote.

BEMBRIDGE LIMESTONE ... 25 FT.
OSBORNE BEDS ... ... 70 FT.
UPPER HEADON ... ... 49 FT. TOTAL).

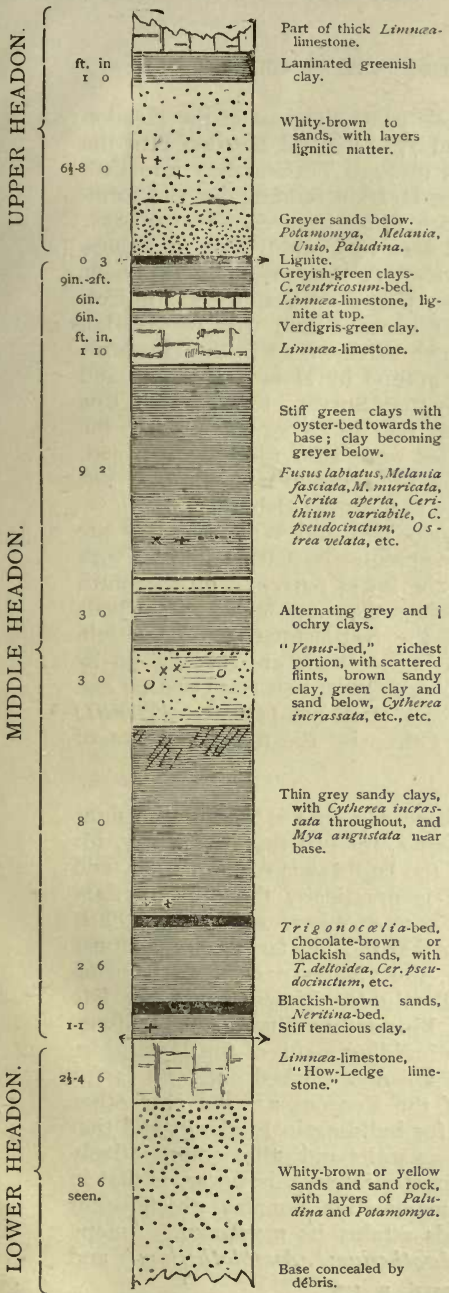
UPPER HEADON.
MIDDLE HEADON.
LOWER HEADON.
ft. in
1 0
6½-8 0
0 3
9in.-2ft.
6in.
6in.
ft. in.
1 10
9 2
3 0
3 0
8 0
2 6
0 6
1-1 3
2½-4 6
8 6 seen.
Part of thick *Limnæa*-limestone.
Laminated greenish clay.
Whity-brown to sands, with layers lignitic matter.
Greyer sands below. *Potamomya, Melania, Unio, Paludina.*
Lignite.
Greyish-green clays-*C. ventricosum*-bed.
Limnæa-limestone, lignite at top.
Verdigris-green clay.
Limnæa-limestone.
Stiff green clays with oyster-bed towards the base; clay becoming greyer below.
Fusus labiatus, Melania fasciata, M. muricata, Nerita aperta, Cerithium variabile, C. pseudocinctum, Ostrea velata, etc.
Alternating grey and ochry clays.
"*Venus*-bed," richest portion, with scattered flints, brown sandy clay, green clay and sand below, *Cytherea incrassata*, etc., etc.
Thin grey sandy clays, with *Cytherea incrassata* throughout, and *Mya angustata* near base.
Trigonocœlia-bed, chocolate-brown or blackish sands, with *T. deltoidea, Cer. pseudocinctum*, etc.
Blackish-brown sands, *Neritina*-bed.
Stiff tenacious clay.
Limnæa-limestone, "How-Ledge limestone."
Whity-brown or yellow sands and sand rock, with layers of *Paludina* and *Potamomya*.
Base concealed by débris.

FIG. 76.—VERTICAL SECTION OF BEDS AT THE N.E. CORNER OF HEADON HILL. (Scale 8ft.=1in.).—*Keeping and Tawney.*

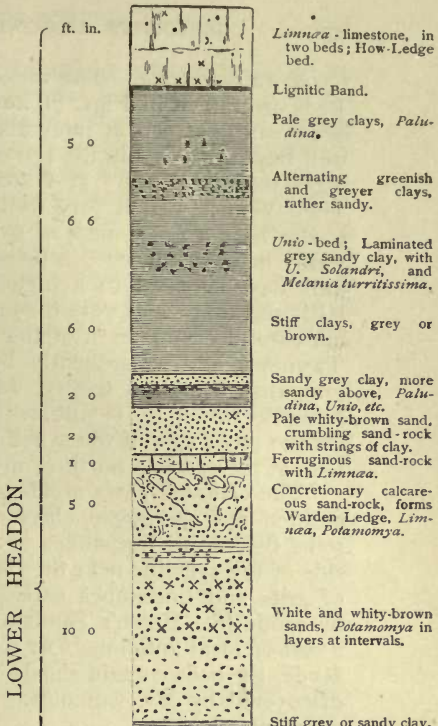
LOWER HEADON.
ft. in.
5 0
6 6
6 0
2 0
2 9
1 0
5 0
10 0
2 0
3 0
1 3
3½-4 0
0 6
2 0
0 8
5 0
0 6-8
2 0
0 4
4-4 6
0 6
1 6
Limnæa-limestone, in two beds; How-Ledge bed.
Lignitic Band.
Pale grey clays, *Paludina.*
Alternating greenish and greyer clays, rather sandy.
Unio-bed; Laminated grey sandy clay, with *U. Solandri*, and *Melania turritissima.*
Stiff clays, grey or brown.
Sandy grey clay, more sandy above, *Paludina, Unio, etc.*
Pale whity-brown sand, crumbling sand-rock with strings of clay.
Ferruginous sand-rock with *Limnæa.*
Concretionary calcareous sand-rock, forms Warden Ledge, *Limnæa, Potamomya.*
White and whity-brown sands, *Potamomya* in layers at intervals.
Stiff grey or sandy clay, *Potamomya.*
Lignitic band.
Greenish clay, *Potamomya.*
Buff-coloured limestone, *Limnæa.*
Lignitic band.
Greenish grey clays.
Soft crumbling limestone, *Limnæa.*
Grey marly clay.
Buff limestone, *Limnæa.*
Greenish clay.
Buff compact limestone, *Chara*-seeds.
Whity-brown sand-rock.
Buff limestone, *Chara*-sds.
Carbonaceous layer.
Green clay.
Nodular ironstone band.
Pale yellowish sands.
TOTAL .. 70—71 feet.

FIG. 77.—VERTICAL SECTION OF LOWER HEADON (FRESHWATER) BEDS EXPOSED BETWEEN WESTON CHINE AND WARDEN CLIFF. (Scale 12 ft.=1 in.)—*Keeping and Tawney.*

For full particulars of these sections see *Quart. Journ. Geol. Soc.*, vol. xxxvii, pp. 91 and 98, from which they are by permission, reproduced.

Cytheræa incrassata. The various local divisions of the Headon Beds are shown in Figs. 76 and 77. Beyond Headon Hill the beds can be traced at intervals through Totland Bay into Colwell Bay, the sands in the Lower Headon running out and forming a reef or "ledge" at Warden Point between the two bays. The "Venus" bed is very well seen in Colwell Bay, and there is also here a great mass of oysters *(Ostrea velata).* Professor Judd* in 1880 advanced a theory that the "Venus Bed" in Colwell Bay belonged to a higher horizon than that of Headon Hill, and that there were thus two marine beds in the Headons, but careful examination of the ground by Messrs. Keeping and Tawney,† and subsequently by the Survey, showed that this somewhat ingenious theory was not in accordance with the evidence which those authorities were able to bring forward. On the other side of the syncline the Headon Beds are only just seen at the extreme north of the island near Osborne.

The *Osborne Beds* at Headon Hill and Whitecliff Bay are mottled red and green clays containing estuarine fossils, with some freshwater limestones in the lower part, but on the north side of the syncline near St. Helens there are much harder beds of grits and limestones called the Nettlestone Grits, overlain by sands (St. Helen's Sands). These beds are brought up by a sort of local anticline. At King's Quay, between Osborne and Ryde, the beds contain shoals of a small fish *(Clupea vectensis)* discovered by Mr. Colenutt. Otherwise the fossils are not of great interest.‡

The *Bembridge Limestone* succeeds, and is one of the most interesting beds of the whole series, for two reasons: firstly, for the insight which it gives us of the land fauna of the period, and secondly, for the fact that it is practically the only Tertiary building-stone in England. Those members who visited Paris at Easter, 1908, will remember that the Tertiary building-stones there are of great importance, the greater part of Paris being in fact built of them. The Bembridge Limestone of the Isle of Wight, under the name of Binstead or Quarr Abbey Stone, has furnished the material for building many of the Hampshire churches, though the quarries are now worked out. So far as I know, the Sarsen Stones of the Eocenes are the only other material of Tertiary age used for building in England, and that to a limited extent only, such as walls and other comparatively rough work.§ The point of greater interest, however, is that in this limestone the series of mammalian remains which occur throughout the Oligocene Beds attains its maximum. Among other forms found are *Palæotherium*, *Anoplotherium*, and

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* *Quart. Journ. Geol. Soc.*, vol. xxxvi, p. 137.

† *Quart. Journ. Geol. Soc.*, vol. xxxvii, p. 85.

‡ See Note at end of this chapter.

§ The shell-bed in the Barton Beds of the mainland is mentioned by Mr. Monckton at p. 282 as a building-stone.

Chœropotamus. The same are found in similar beds in the Paris Basin. There also occur several land shells such as the large *Achatina costellata*, *Bulimus ellipticus*, and *Helix globosa* and several other species of *Helix*. The usual freshwater genera are also found in abundance, such as *Limnæa* and *Planorbis*. The beds are about 20 ft. thick and occur on the top of Headon Hill (see Fig. 71) and again at Cliff End and Sconce Point on the east side of Colwell Bay. They also form the extreme eastern point of the island at the Foreland and extend round to Bembridge Point (see Figs. 72 and 74). On the north side of the syncline they are seen at Hamstead and Gurnard Ledges, and at Binstead near Quarr Abbey, where, as has already been said, they were formerly extensively quarried.

They are succeeded by the *Bembridge Marls*, which are about 100 ft. thick and are mostly of estuarine origin. They generally, however, contain a bed of oysters at the base, which is well seen at Whitecliff Bay, and at St. Helen's there is a purely marine bed just above the oysters, with *Arca websteri*, *Mytilus affinis*, *Mya minor*, etc. The beds are exposed at Bouldnor, Hamstead, and in Thorness Bay, as well as at Whitecliff Bay and St. Helens. At Gurnard Ledge, about 3 ft. above the Bembridge Limestone and Oyster Beds, is a band of limestone about 3 inches thick, containing abundant remains of insects.

The last of the series, the *Hamstead Beds*, form the centre of the syncline and cover a large extent of ground throughout the north half of the island. They can, however, only be studied with advantage at Hamstead, where they form the whole of the cliff and are about 250 ft. thick. They are divided into two beds, the lower or estuarine beds, and the upper (marine) series. At the base, separating them from the Bembridge Marls, is a conspicuous bed called the "Black Band." This is a tough carbonaceous clay with lignite and vegetable remains containing many fossils, such as *Paludina*, *Hydrobia*, etc. About 60 ft. above this is the "White Band," composed of several layers of shelly clays full of fossils, mostly *Melania*, *Cerithium* and *Cyrena*. These beds contain mammalian remains, such as *Hyopotamus*, specimens of which, such as jaws or single teeth, are frequently found on the shore washed out of the cliffs, but are not easy to find in the beds themselves. The marine series is the uppermost 30 ft. and contains many specimens of *Corbula pisum*, *Corbula vectensis*, *Cerithium plicatum*, and *C. elegans*, as well as the rarer *Voluta rathieri*. At the very top is a bed with *Ostrea callifera*, the highest Tertiary bed in the island.

POST-TERTIARY.

The Post-Tertiary Beds consist of *Plateau Gravels*, *Clay with Flints*, *River Gravels*, and *Alluvium*.

The *Plateau Gravels* occur on Headon Hill (see Fig. 71) and on many of the other hills, such as St. George's Down, Hamstead, Calbourne, and the neighbourhood of Cowes and Osborne.

The *Clay with Flints* is found both on the central ridge and the Southern Downs, and represents the waste of the Chalk. It is interesting to find it on some of the Lower Chalk Hills, showing that the Chalk with flints was formerly present over all this area. The flints in this deposit are unworn in contrast to those of the Plateau Gravels, which are often well rolled.

The *River Gravels* are of interest as marking the old courses of the rivers, as has already been explained in regard to the tributaries of the Western Yar. These gravels contain mammoth and other remains, as at Freshwater.

Under *Alluvium* may be included such beds as the sands with hazel nuts in Compton Bay and the tufaceous deposits in Totland Bay.

NOTE.—Since this chapter has been in type a very interesting contribution has appeared in our PROCEEDINGS from the pen of M. Dollfus,* under whose guidance the Association recently studied the Tertiary beds of the Paris Basin. He carefully compares the French and English deposits, and he comes to the conclusion on palæontological evidence that the Headon Beds are more allied to the Barton than to the Bembridge, and should be classed with the Eocene. The Bembridge Beds are undoubtedly Oligocene, and so, in his opinion, are the Osborne Beds, though it may be pointed out that some of the fossils on which he bases this conclusion have been also quoted from the Headon Beds. He, however, justly remarks that "the palæontology of the Tertiary of the Isle of Wight requires a very careful revision."

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* "On the Classification of the Beds of the Paris Basin," *Proc. Geol. Assoc.*, vol. xxi, p. 101.

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